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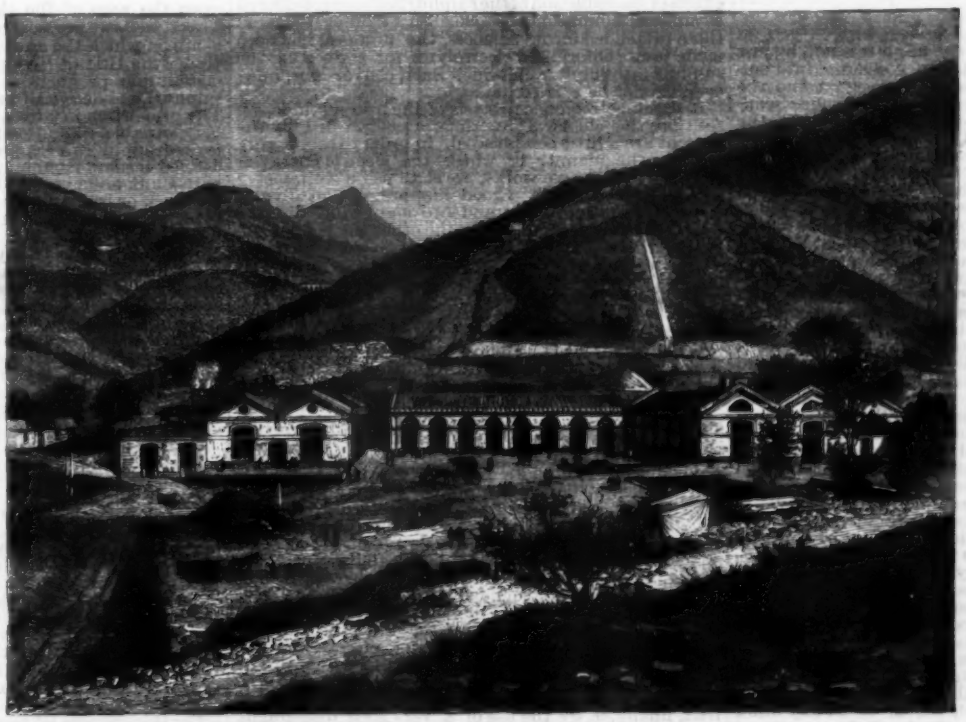
THE ELECTROMETALLURGIC TREATMENT OF COPPER MATTE FOR THE EXTRACTION OF COPPER.

AMONG the different applications of electricity to the industries, the extraction of metals from their ores is, without doubt, one of the most important. For this reason it has for a long time been a subject of study among scientists, and, as regards this, it will suffice to recall the fine experiments of Mr. Becquerel upon the treatment of silver and copper ores.

Yet these methods of extraction have never been able to give any practical result, on account of the impossibility of producing very intense currents by simple means and at slight expense. But when the Gramme machine made its appearance, and after the Nord-Deutsche Affinerie at Hamburg had demonstrated that electric energy could be effectively employed for refining large quantities of crude copper, the question of electrolytic processes for the large industries was taken up again with an increased interest. In the long series of processes which have been patented by inventors, we shall confine ourselves to a mention of those of Messrs. Mascazzini and Parodi, followed by Mr. Letrange, for the treatment of zinc by the electrolysis of its sulphate; of Messrs. Luckow and Deligny, who proposed to substitute ores for anodes; of Messrs. Miest and Blas for electrolytic extraction in general; of Keith for lead; of Graetzel for aluminum and magnesium; of Baker for gold; and of Cobley, Andre, and many others whom we pass over. Unfortunately, these patents seem to demonstrate the desire of the inventors to propose any solution whatever rather than the results of accurate work and serious research. In reality, it is only the refining of copper that can be worked with profit, and there are now several works that refine this metal by means of the electric current.

Another progress has just been made by the Electrometallurgic Society of Genoa, which is working Mr. E. Marchese's patent, and which is delivering to the trade electrolytic copper extracted from copper matte.* It will not prove without interest, then, to give a detailed description of the method followed in the Sestri-Levante establishment, which belongs to the society just named, and which we illustrate herewith.



THE SESTRI-LEVANTE ELECTROLYTIC ESTABLISHMENT.

LABORATORY EXPERIMENTS.

In order to make the treatment under consideration better understood, it will be well to begin with a few preliminary researches that have been made in the laboratory.

From the conductor, A B (Fig. 1), which forms part of an electric circuit derived from any generator (a Gramme machine, for example), let us divert a portion of the current by the two points *a* and *b*, one of which is capable of sliding freely upon the conductor. In this way, on causing the resistance of the latter to vary, we may obtain between these two points any difference in potential that we desire.

Let us now place the two points in communication, on the one hand with an apparatus designed for measuring differences in potentials (a Clark potentimeter or a Lipmann capillary electrometer), and on the other with a sulphate of copper voltameter having platinum electrodes. In the experiments that follow, it is well to give the anode a very wide surface in order to diminish the voltameter's resistance, and to make the cathode smaller in order to more easily observe the deposits that will eventually form thereon.

If, when a current is sent in the direction shown by the arrow, the difference of potentials between *a* and *b* equals 2 volts, there will occur a decomposition of copper sulphate into metallic copper, which will deposit upon the cathode, and into oxygen and sulphuric acid, which will betake themselves to the anode. If, on the contrary, the difference is but 1 volt, no decomposition will take place.

Between the two electromotive forces employed, we shall find the value for which the electrolysis of the copper sulphate begins to take place. Such value has been termed the "limit electromotive force," and it represents the minimum work that is necessary to cause the chemical decomposition of the copper sulphate. As such work may likewise be measured by the number of heat units that are necessary to overcome the affinities which unite the copper with the oxygen and sulphuric acid, that is to say, by 28,200 heat units (according to thermo-chemical data), it will be seen that there exists a well defined ratio between the limit electromotive force and the number of heat units that are necessary to effect the electrolysis of the salt in question.

The formula

$$E = 4{\cdot}16\,\varepsilon\,C,$$

in which we have

E = limit electromotive force,
C = heat units of the reaction,
ε = electrochemical equivalent of the metal that forms the base of the salt to be electrolyzed,

gives a means of passing from electromotive forces to heat units, and conversely, when the chemical reactions are sharply defined.

Upon always preserving a difference of potential equal to 2 volts between the electrodes of the voltameter, the solution will soon undergo alteration. In measure as the copper deposits upon the cathode, the sulphate in the solution will diminish and be replaced by an equivalent quantity of water; that is to say, by the sulphuric acid derived from the electrolysis.

The electric energy that traverses this solution is not all employed in precipitating the copper, but accomplishes other work. This fact is demonstrated with sufficient clearness by the following experiment:

Let us arrange two sulphate of copper voltameters (Fig. 2) for tension—one of them being provided with copper electrodes and the other with platinum ones—and let us leave between *a* and *b* a difference of potentials equal to 2 volts. If at various intervals we weigh the copper deposited upon the two cathodes, we shall find that the weights of the two deposits of copper are equal only at the beginning, and that they afterward differ more and more until the electrode voltameter no longer contains anything but sulphuric acid, and that too although the same number of amperes is traversing the two voltameters. The difference in weights is due to the portion of the current that is acting upon the sulphuric acid.

The above method may be effectively employed every time that it becomes a question of the electrolysis of several mixed liquids. It gives the ratio between the coulombs furnished by the generator and the weight of the metal deposited, from whence we deduce the yield of the process that we desire to employ. Theoretically, if, in the electrolysis of copper sulphate, we employed potentials capable of furnishing an energy greater than the 28,200 heat units that are indispensable for the decomposition, and less than the 34,500 that are necessary to decompose the sulphate of water into oxygen and hydrogen, we should have to avoid this second work of the current. But in reality it is not so, since the resultant of the electrolysis of the acid is not only a production of free oxygen and hydrogen gases, but also that of the oxides, hydrides, and other compounds which much reduce the limit electromotive force for the decomposition of the water. It is a fact noted by several chemists that one daniell suffices to effect the decomposition of water between platinum electrodes.

The electrolysis of solutions of copper sulphate has been performed on a large scale at Ocker with the use of three Siemens machines and a daily production of nearly 800 kilog. According to information that has been published with too little detail, it seems that the precipitating backs, twelve in number, were arranged for quantity. Although no mention is made of the quality of the anodes and of the resistance of the backs, we suppose that these elements were so selected as to preserve a difference of 3 volts in the potentials, measured at the terminals of the dynamo. However this may be, we find in the memoir published upon this treatment in the *Electrotechnische Zeitschrift* an assertion that merits discussion. In fact, it is said therein that a half per cent. of impurities (iron sulphate) contained in the solutions employed in the electrolysis suffices to give rise to a strong polarization which, to be overcome, requires higher potentials, and consequently a greater expenditure of work. From this, if by polarization we understand counter-electromotive force produced by the disengagement of the oxygen gas upon the anode, we may assert that the presence of sulphate of iron in an acid solution of copper sulphate, far from producing a polarization, is an excellent means of entirely avoiding it. In fact, we have seen above that for the electrolysis of copper sulphate it is necessary to employ an electromotive force of nearly 2 volts in producing oxygen gas, while it takes a difference of potential equal to but 1 volt to have copper from a mixture of copper sulphate, iron sulphate, and sulphuric acid; and, under these circumstances, we have no further development of oxygen, this being entirely employed in peroxidizing the iron protosulphate. Moreover, in general, in electrolytic operations, high potentials produce polarization instead of overcoming it.

In pursuing our experiments, let us substitute a plate of pure copper for the platinum anode in the voltameter shown in Fig. 1, and seek the distance between the points *a* and *b* for which copper is seen to appear upon the cathode. The potentimeter will reveal a limit electromotive force of no more than a fraction of a volt. This low electric energy cannot effect any chemical decomposition, but merely intervenes to carry copper from the anode to the cathode, although we do not know how electricity accomplishes this operation. This phenomenon, which forms the basis of the electrolytic refining of crude copper, however simple it may appear, has been many times inaccurately explained.

The supposition has been made that there is a preliminary decomposition of the sulphate of copper operated by the electric current—a thing that is absolutely impossible at such tensions; and the regeneration of the copper sulphate at the anode has been explained by a purely chemical secondary effect, due to the fact that the copper is surrounded with oxygen and sulphuric acid. Yet the fact that there is no development of oxygen upon the anode and no traces of free sulphuric acid in the liquid, if very low potentials are operated with, in no wise confirms this view.

As long ago as 1877, Mr. Gramme published in the *Revue Industrielle* a *resume* of numerous experiments that had been performed by him in order to show the advantage that could be derived from the use of the electric current in the refining of copper. He demonstrated that, with a given quantity of mechanical work converted into electricity, almost indefinite masses of copper could be refined, provided that the surfaces of the electrodes were increased in proportion so as to keep constant the resistance of the external circuit required by the machine. For this purpose he employed backs arranged for tension, and increased the number of these and the surfaces of the electrodes for each series of experiments. According to his statement, solutions of copper sulphate under such circumstances must be considered as if they were simple metallic conductors for whose heating there would be employed the entire energy produced by the generator. Nevertheless, the carriage of the metal from one pole to the other requires a certain energy—very small if you wish, but of a different nature from that expended for the heating of the conductors. It would prove very useful to have exact measurements for determining the value of this work in the different metals and for the different salts of the same metal, but, up to the present, data of this kind are entirely wanting.

* Under this term is embraced all metallurgic products composed of copper, iron, and sulphur, and derived from the fusion of pyritous ores.

In the mean time, let us pursue our experiments with soluble anodes. In the voltameter shown in Fig. 1 let us remove the copper anode, and substitute therefor a plate of copper sulphide corresponding to the formula CuS. Such a plate may be had by strongly compressing in a mould some copper sulphide obtained by precipitation with sulphuric acid developed in a soluble salt of copper, or by melting copper with a large excess of sulphur; but in the last case the operation must be performed with care, so as not to obtain Cu_2S, which is a very bad conductor of electricity.

It takes an electromotive force of less than one volt to effect the electrolysis of the couple, copper sulphide—copper sulphate—copper.

After prolonging the passage of the current through this couple for a certain length of time, it will be found that the copper of the cathode has increased by just the weight lost in the anode, that no longer contains anything but metalloid sulphur with undecomposed copper sulphide, while the solution has always remained unaltered. In the above-named couple, copper nitrate may be substituted for the sulphate without in any way changing the result of the experiment. If there is a decomposition of the salt into cop-

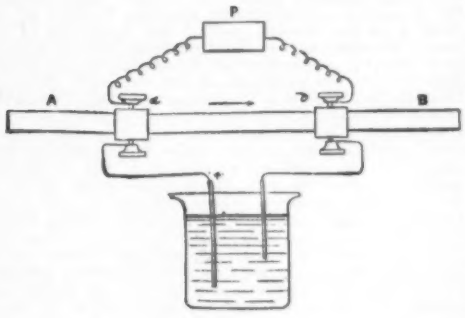


FIG. 1.

per on the one hand, and nitric acid with oxygen on the other, how comes it that the sulphur is not, by just as powerful a means of oxidation, converted into sulphuric acid? In fact, in the anode we again find the sulphur that was combined with the copper, and chemical analysis shows us to traces of sulphuric acid in the solution of copper nitrate. The energy of the electric current acts, then, solely to separate the sulphur from the copper and to carry the latter from the anode to the cathode, and, under such circumstances, there is nothing to prevent the assertion that sulphides are electrolyzable—a fact that would seem not to be in accord with the opinion generally held by electricians that electrolysis can only occur when the substances to be electrolyzed are in a liquid state. This fact sufficiently proves that the regeneration of the sulphate of copper at the expense of the anode is not a secondary chemical action, but simply the effect of electric work. Apropos of this, it is well to observe that recourse is too often had to reactions called secondary in order to explain electrolytic phenomena that are very simple.

It would be more correct to endeavor to find out every time, by actual experiment, whether these chemical reactions are not rather the consequence of mechanical work. In many electrolytic decompositions one would be led to believe that the electric current prevents a host of chemical reactions that might occur were they not subjected to the action of electricity.

Without going far for proof of these facts, it will suffice to mention the following, which are known by those who occupy themselves with electricity.

I. The method of electrolytic trials for the estimation of copper is employed now in almost all laboratories. As well known, it is necessary in this method to prepare a solution of the products to be analyzed that shall contain copper in the state of nitrate, and to pass an electric current through this solution until the copper has been completely deposited upon a platinum cone. After this operation, the liquid no longer contains anything but nitric acid, which, under any other circumstances, would have dissolved the copper at once. But the electric action absolutely prevents such

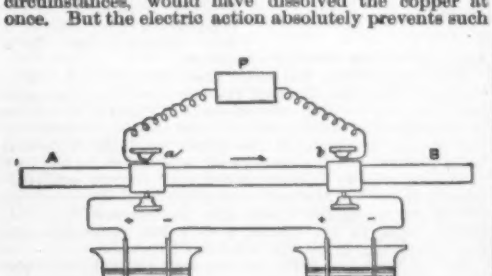


FIG. 2.

a solution occurring. It is only necessary to interrupt the current to see the copper disappear.

II. The action of sulphuric acid upon iron sulphide, by producing iron sulphate and hydrosulphuric acid, is exerted with facility every time the two substances come into contact, but ceases to occur when the iron sulphide employed for the anode is submitted to the action of an electric current, so much the more intense in proportion as the concentration of the liquid is greater. One might, moreover, multiply these facts at his pleasure, but this is not our present intention.

Let us return to the electrolysis of the copper sulphide. It will be seen that if it were possible to have ores or metallurgic products that contained only copper and sulphur without the presence of iron, the extraction of the copper would be no more difficult than the refining of the crude metal. Unfortunately, the copper is always accompanied with iron in proportions that greatly vary, but that are always large, and the methods for getting rid of this metal before electrolysis are too complicated and too expensive; so that it is necessary to resign ourselves to a careful study of the influence that iron exerts in electro-metallurgic processes with copper, and to ascertain whether there is a means of getting a good deposit and an economic yield by using as anodes copper mattes derived from concentrating furnaces. Starting from the simplest cases and proceeding to the most difficult, we shall see that this is possible. For this purpose let us use the same voltameter as before, and substitute an iron sulphide plate for the copper sulphide one.

The copper begins to deposit upon the cathode when the difference of potential between a *and* b *is much less than one volt.*

After the passage of the current the solution at once alters, and, if the experiment be sufficiently prolonged, chemical analysis will demonstrate that, instead of copper sulphate, which has entirely disappeared, we have the following substances:

Basic persulphate of iron (Fe_2O_3,$2SO_3$),
Protosulphate of iron,
Sulphuric acid.

This deposit preserves its fine quality as long as the solution still contains 0·1 gr. of copper per 100 cubic centimeters of liquid. From this instant the copper begins to become pulverulent and black, and hydrogen gas is disengaged from the cathode. By the use of two sulphate of copper voltameters (Fig. 2) arranged for tension, the anode of one being of copper, and that of the other of iron sulphide, we may find by successive weighings that the deposit in the sulphide of iron voltameter rapidly diminishes, while the deposit in the other keeps nearly constant. This shows, first, that electricity performs other chemical work than the depositing of copper, and, second, that neither the changes in chemical composition undergone by the liquid nor the separation of the sulphur derived from the electrolysis of the iron sulphide appreciably modifies the voltameter's resistance. The opposition made to this process, then, is without any foundation, although the increase in resistance produced in the backs through the effects of the reduction of the sulphur hasbeen considered as an insurmountable obstacle. So, in order to avoid these pretended inconveniences, the proposal has been made to use chloridized electrolytes for converting the sulphur into sulphur chloride. Such conversions, however, cannot be carried out.

Returning to our electrolysis of the iron sulphide, we see that the chemical reactions accomplished by the current are a little complicated. In order to thoroughly examine the manner in which the electric energy is distributed in these works, we shall use a voltameter (Fig. 3) provided with a good diaphragm that divides it into two compartments, and into one of which dips the iron sulphide anode, and into the other the copper sulphide cathode. We shall fill these two compartments with a solution of copper sulphate, and pass an electric current thereinto, as before, while preserving between *a* and *b* a difference of potentials equal to one volt, this being, as we have above seen, more than enough to cause the copper to deposit.

What will occur is as follows: In the compartment *n*, the copper will, for the entire duration of the experiment, preserve a perfect brilliancy, and the solution will undergo no perceptible alteration, but will be impoverished only. In the compartment *m*, we will find again in the anode some metalloid sulphur mixed with undecomposed iron sulphide. The solution will contain no more copper sulphate, but the place of the latter will be taken by basic persulphate of iron and free sulphuric acid, that is to say, uncombined with iron. Finally, there will be no trace of iron protosulphate. If to this same voltameter there be added, in tension, a second copper sulphate voltameter and copper electrodes (Fig. 4), the deposits in the two apparatus will be nearly equal. It is concluded from this that the basic persulphate of iron, with the sulphuric acid, forms at the side where the anode is situated; that the iron protosulphate comes from the reduction of the ferric persulphate when the latter is near the cathode; that this reduction is electric work and not a secondary action, and consequently requires an expenditure of energy; and that, finally, if, by the use of a very good diaphragm, we prevent a contact of the persulphate with the cathode, there will no longer be any reduction, and all the armperes that traverse the couple will be employed in depositing copper. It is for this reason that the deposits in the two voltameters do not differ.

The use of iron sulphide anodes would form the basis of a good electrolytic treatment for solutions of copper sulphate, provided that diaphragms of good quality and low enough price could be found.

This method, as compared with the one in use at the Ocker works, offers the great advantage of expending much less work than if it concerned the simple electrolysis of copper sulphate with lead or carbon anodes: first, because the reaction with the iron sulphide requires an electromotive force of less than one volt instead of the three volts necessary to the other; second, because the current would work entirely upon the copper instead of distributing itself between the copper and sulphuric acid, as occurs at Ocker.

In order to obtain a counter-proof of the fact that the presence of ferric persulphate in the cathode absorbs a portion of the electric work, it will suffice to add to the compartment *n* (Fig. 4), when it contains only copper sulphate, a few drops of a solution of iron persulphate, allow the current to pass for some time, and again weigh the cathodes of the two voltameters. The difference in weights will at once appear, and, in the solution, analysis will no longer show ferric persulphate, but, in its stead, iron protosulphate, although the copper, as long as there is any ferric persulphate in the solution, will preserve its brilliancy and coherence. This latter circumstance is of some interest, because it confirms the fact that the reduction of the persulphate is not the consequence of a secondary action due to the copper that partially redissolves in the solution. In fact, the dissolving action of the persulphate of iron would produce upon the surface of the deposited metal more or less irregular corrosions, and, in general, a disorder in the molecular arrangement incompatible with the effect of a deposit without blemish.

As soon as the persulphate of iron is in great part reduced, the copper soon changes its qualities, and the disengagement of hydrogen shows that electric action is beginning to reach the sulphuric acid. Let us put some acidulated protosulphate of iron into the two compartments, and an anode of iron sulphide into *m*, of the diaphragm voltameter shown in Fig. 3. The result of the electrolysis will be a disengagement of hydrogen upon the cathode and a peroxidation of the protosulphate upon the anode, while the iron of the sulphide will be reduced and dissolved. So for this decomposition it suffices to dispose of an electromotive force of less than one volt.

If, letting every other circumstance be equal, we replace the iron sulphide anode by one of copper sulphide, we shall have, after the electrolysis, a disengagement of hydrogen upon the cathode and a production of copper sulphate upon the anode, at the expense of the copper that it contains, which the protosulphate peroxidizes in a slight proportion. The electric action is here divided between the production of sulphate of copper and the peroxidation of the salt of iron, that is to say, it operates partly upon the anode and partly

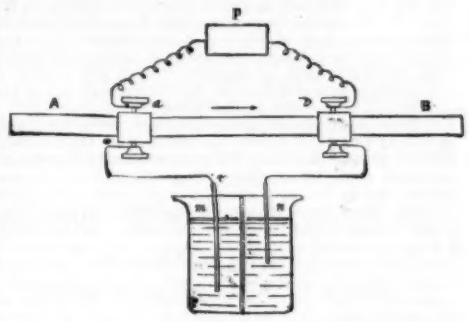


FIG. 3.

upon the zone of the electrolyte opposite the anode. This stated, we are now ready to proceed to the experiments in which the anodes are furnished by the matte. Under the title of "copper mattes" are comprised all metallurgic products composed of copper, iron, and sulphur, and derived from the fusion of pyritous ores. The proportion in which these three bodies is found is very variable, so mattes must be considered as a mixture of sulphides of copper and iron rather than well defined ternary combinations. In a rich matte we meet with Cu_2S, and even with Cu in capillary filaments, and FeS, or iron sulphides, which for one equivalent of metal contain less than one of sulphur. In poor mattes the sulphides CuS and Fe_2S_3 are in larger quantity. Mattes conduct electricity very well, and, if they are employed as anodes, we must expect to see the same phenomena that we observed when we effected the electrolysis of iron sulphide and copper sulphide separately. This is in fact what happens. The couple composed of *matte, copper sulphate, and copper gives copper with the use of an electromotive force of much more than one volt.* The transformations that the electrolyte undergoes are of the same nature as those that we have examined above, that is to say, there is a production of

Basic sulphate of iron,
Ferrous protosulphate,
Free sulphuric acid.

We have seen that the deposit preserves its fine quality up to the moment at which there is no disengagement of hydrogen upon the cathode, and that such disengagement is entirely avoided when things are so arranged as to always have a certain quantity of persulphate of iron in the liquid. On another hand, we know that this persulphate, whose presence is necessary in order to obtain a good deposit, consumes a portion of the electric energy. We conclude from this that the production of pure electrolytic copper in the presence of iron costs more work than when we operate without this metal. Let us now see between what limits this expenditure of work is comprised, in order to determine the yield of the process.

For this purpose let us suppose that we use a solution that contains the quantity of copper necessary to convert all the iron of the anode into soluble sulphate, that is to say, that the copper is to the iron as three

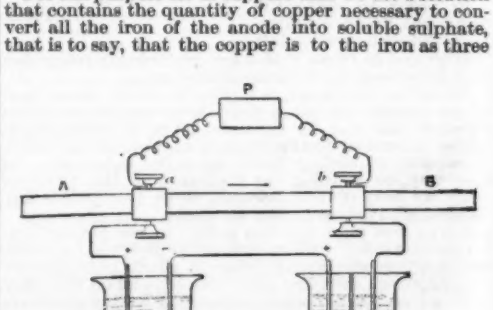


FIG. 4.

times the equivalent of the copper and as two times that of the iron; and let us suppose besides that the copper contained in the matte is equal to that of the iron. In causing a current to traverse the couple composed of *iron sulphide, copper sulphide—copper sulphate, copper*, we may admit that the amperes will be divided into equal parts upon the copper and iron of the anodes, because the metallic resistances offered by iron and copper sulphides have nearly the same value.

The half of the current that traverses the couple composed of *copper sulphide, copper sulphate, and copper* will operate without any loss, and there will be, in proportion, as many grammes of copper as of coulombs that will pass. The other half of the current, that traverses the couple composed of *iron sulphide, copper*

sulphate, and *copper*, operates at first only upon the copper, and finally in the reduction of the iron salts; so that, with the same number of coulombs, no more than half the copper is deposited. Consequently, with anodes in which the copper and iron are of equal weight, we may calculate upon a rendering of 75% of the electric energy employed. If the copper increases, the rendering will be greater, and, on the contrary, less if it diminishes. It cannot, however, get below the 50% that is obtained when there is no longer any copper in the anodes.

What is essentially striking in all these experiments is that it has never been necessary to employ potentials greater than one volt; on the contrary, the tensions have always remained below that figure.

Although we have accurately determined the limit electromotive forces of each couple, we do not think it necessary to give a *resumé* thereof. Since the metallic sulphides obtained through fusion not being definite chemical compounds, there result numerous variations for each measurement; and, moreover, such researches, though interesting to science, are not of much help to the industry.

In conclusion, we shall set forth the most important facts that the manufacturer may avail himself of in applying the process. They are as follows:

1. Metallic sulphides obtained through fusion are compounds that conduct electricity very well. From numerous experiments performed in our laboratory with Thomson's double bridge, as modified by Kirchhoff and Hausman, it results that their conductivity comes much nearer that of metals than of that of the electrolytes (except copper sulphide, Cu_2S, which has a very great resistance.

2. The decomposition of the metallic sulphides, employed as anodes, requires an expenditure of work much less than that required by the sulphate.

3. By employing anodes composed of iron-copper-sulphur, such as result from a first ordinary fusion, we may always remove the copper with an electric rendering which is comprised between 50 per cent. in cases where there is no longer any copper in the anodes and 100 per cent. when, on the contrary, there is no more iron.

4. With the use of metallic sulphides for anodes, we may recover in a metalloid state all the sulphur contained in the mattes.

5. Finally, the extraction of copper based upon this process offers an exceptional simplicity as compared with the different metallurgic treatments in use. In fact, we know that the metallurgy of copper requires at least three fusions: that of concentration, that of the production of crude copper, and that of refining. Besides, often-renewed roasting is necessary in order to remove the sulphur completely. In the electrolytic process there is only the production of the matte and its electrolytes in order to at once obtain refined copper.

All these results, which are confirmed by experiment, gave us the hope that we might be able to successfully try this process in a practical manner. Without disguising the numerous difficulties that we had to meet with to carry out these laboratory experiments upon a large scale, and the importance of which will be justly appreciated only by those who are occupying themselves seriously with this question, the full confidence that we had in the correctness of the principles upon which the process was based completely justified the employment of the large capital that has been embarked in it.

Happily, our studies, which were always pursued with constant perseverance, have been crowned with entire success, and we shall now pass in review the different apparatus employed, and the process followed; at the Sestri-Levante Metallurgic Establishment, which is arranged in such a way as to produce two tons of electrolytic copper per day.—*G. Badia, in La Lumiere Electrique.*

THE PRESERVATION OF IRON BY ONE OF ITS OWN OXIDES.*

By Mr. B. H. THWAITE, Assoc. M.I.C.E.

WHEN iron is exposed to contact with ordinary moist atmospheric air, it unites with the oxygen of the latter, to form two varieties of oxide of iron; in the first instance, the ferrous oxide (FeO), which becomes rapidly converted into another, or the second variety, the ferric oxide (Fe_2O_3). If a piece of iron is exposed to oxidizable influences sufficiently long, its entire substance will become oxidized; for as soon as the superficial film of oxide on the surface of the iron becomes converted into the second variety, or ferric oxide, part of its oxygen is transmitted to the metallic surface beneath it to form ferrous oxide, and this latter also becomes in its turn converted into ferric oxide, and again transfers its oxygen to the still remaining metallic iron; and this process goes on continuously until the whole of the iron becomes oxidized. Hence, if iron is not protected from this oxidation, corrosion, or action of decay, its strength becomes in time seriously impaired. As will be seen from the formula† (arranged by the author, and based on a series of experiments on the action of the oxidation of iron, in order to ascertain the metallic life of iron with a tolerable degree of exactitude), it appears that a bar of wrought iron, 4 inches × 1 inch, subjected to the corrosive atmospheric influences of a manufacturing city, would be entirely corroded away in a little over a single century. Fortunately, however, besides the two combinations of iron with oxygen already mentioned, there is a third, or the magnetic oxide, F_3O_4, a most stable oxide, and, as in the examples of the oxides of zinc and copper, once properly formed of a certain thickness, it arrests further oxidation of the iron. It is found in a natural state on the shores of New Zealand, in the form of black titaniferous sand, and although the sea water is constantly washing over it, its stability is apparently unaffected. Lavoisier is credited with the discovery of the artificial formation and stable properties of the magnetic oxide, and the late Mr. Robert Mallet, M.I.C.E., discovered it during one of his experiments. Berthier noticed it when iron was subjected to highly-heated air, and Thirault is said to have produced the magnetic oxide in 1860, in a very peculiar manner. A modification of Thirault's process is now adopted by gun-makers, who, by means of processes, although long and tedious, succeed in obtaining a most beautiful coating of oxide.

The Russian sheet iron is covered with a thin and rather pliable film of this magnetic oxide, but whether this coating of oxide was originally applied by accident or intention, it is impossible to say. An interesting paper, by Dr. Percy, F.R.S., Hon. M.I.C.E., "On the Protection from Atmospheric Action which is imparted to Metals by a Coating of certain of their Iron Oxides respectively," was read at the meeting of the Iron and Steel Institute, in Newcastle-upon-Tyne, in September, 1877.* In Russia and in the United States common use is made of this sheet iron for covering locomotive boilers and steam cylinders, as well as for roofing purposes. Some years ago Professor Barff, F.C.S., while engaged in experiments in peat charring, noticed the formation of this peculiar oxide, in a pipe conveying highly-heated steam, and observed its preservative action on the iron. He at once commenced a series of experiments and investigations which resulted in the elaboration of a process for producing magnetic oxide, for the purpose of preserving the surfaces of iron. Professor Barff's process is a practical adaptation of Lavoisier's principle. In his specification, Professor Barff describes the process as follows: "In carrying out my invention, I place the objects composed of iron or steel in a muffle or chamber, so constructed as that it may be in part wholly closed, and so that the contents of the interior of such muffle or chamber may be raised, by means of external heat, to an elevated temperature, and when the objects or articles have acquired a temperature sufficiently elevated to cause the decomposition of steam or aqueous vapor when brought into contact therewith, I inject the same, and continue the action of the steam, or the aqueous vapor, until the desired protective film or coating of oxide has been produced." On hearing of Professor Barff's process, it occurred to Mr. George Bower that highly-heated air might possibly be used with success for obtaining a coating of magnetic oxide. Mr. Bower made a series of experiments with air as an agent, and a sample of iron that was subjected to one of Messrs. Cochrane's hot-blast stoves was found to have a most decided and adherent coating of magnetic oxide. The first furnace devised for carrying out the air process consisted of an externally-heated chamber, in which the iron articles to be treated were placed. When the iron articles had attained the temperature of oxidation, a few cubic feet of ordinary atmospheric air were blown into the chamber, which was closed, and the iron then entered into combination with the oxygen of the air, a thin film of magnetic oxide being formed on the metal. Fresh air was admitted from time to time, to replenish the oxygen appropriated by the iron, until the requisite thickness of oxide was attained.

The difficulty and expense of the application of external heat were so great that it occurred to Mr. Bower's son, who was conducting experiments, that, if internal application of heat could be substituted, and the coating of magnetic oxide produced simultaneously with the action of heating, by a series of oxidizing and deoxidizing operations, the process would be much simplified, be more effective, and far less costly. Elaborate experiments were conducted with this aim, and the results far exceeded anticipation. On the basis somewhat of a special furnace, devised and arranged by the author, Mr. Anthony S. Bower developed a furnace for carrying out this process. In this furnace the combustible gases are generated in three producers (in the furnaces first designed, an ordinary single Siemens producer, with inclined plates, was used, but owing to the irregular supply and quality of the gas, it was decided to adopt three). By this arrangement a regular plenum of gas can always be obtained; moreover, the producers are admirably adapted to the form of the furnace. They not only act as buttresses to resist the thrust of the furnace arch, but they prevent wasteful radiation. Coals are charged through specially devised plug hoppers. The plugs, in being withdrawn, permit the coals to fall into the producers with a minimum escape of gas. The Siemens balanced coal-charging boxes were tried, but they were abandoned in favor of the form described. The gases evolved by the distillation of the coal pass over partition walls, descending by a downcast, in which is fixed a regulating valve. The gas then passes along a horizontal flue to the mouth of the combustion chamber, when it meets the current of heated air ascending from the recuperators. Combustion here ensues, perfect mixing and oxidation of the gases being attained by a series of intercepting checker walls; the products of combustion then pass into a side flue, where they ascend into the furnace or muffle. The products of combustion descend from the muffle into a side flue, passing from thence into the recuperator, where, by going round air tubes of fireclay, they transmit their heat to the air flowing to support combustion. The products of combustion then escape into the chimney flue. The air passes into the recuperators by means of a regulating valve, and after flowing through the whole length of the tubes in the recuperator chamber twice, it ascends into a port, where it meets the combustible gases coming from the producers.

The cast-iron articles to be treated are placed in the chamber or muffle, and gradually heated by combustion of producer-gas within the chamber up to the temperature of oxidation, say 1,600° Fahr. The oxidizing process is then commenced, first by submitting the iron to an oxidizing flame, that is to say, by allowing highly-heated air in excess of that necessary for combustion to enter the furnace. The oxygen of this air in excess enters into a double combination with the iron. On the immediate surface of the iron a film or coating of the magnetic oxide (Fe_3O_4) is formed, and over this a film of sesquioxide (Fe_2O_3). This oxidizing operation generally occupies about twenty minutes. The air-valve is then entirely closed, and the combustible gases from the producers (carbon monoxide, etc.) are allowed to enter unconsumed into the muffle. By this operation, a deoxidizing one, the sesquioxide is converted into the magnetic oxide; this deoxidizing operation generally occupies from fifteen to twenty-five minutes, the duration entirely depending upon the quality of the coal-gas. The richer it is in carbon, the less the time required to effect the deoxidizing operation. The air-valve is now opened, and another double combination of oxygen and iron effected, which, by another deoxidizing operation, is reduced to one combination of Fe_3O_4, the magnetic oxide. It will be understood that by repeating the alternate operations of oxidation and deoxidation sufficiently often, the entire metal could be oxidized. The duration of the process depends upon the size, number, and intended use of the articles. For instance, only six double-oxidizing and deoxidizing periods are necessary for articles intended for internal or indoor use. For articles intended to be subjected to external atmospheric influences, from ten to twelve double periods of oxidation and deoxidation are necessary. Owing to the great sensitiveness of wrought malleable iron and steel to oxidizable influences the Bower process produces the coating of oxide in these varieties too rapidly, and it is not sufficiently uniform or adherent; and the Barff process has been found by experience to be more satisfactory for producing the magnetic oxide coating on the surfaces of malleable wrought iron and steel.

However, the two inventors combined their respective processes, and a furnace having the economic features of the Bower furnace was designed to effect the Barff process. In the preliminary experiments great difficulty was found in obtaining a satisfactory and durable form of steam superheater. Circular coils of lap-welded steam-pipes were first tried, but, although effective as superheaters, their cost and liability to stoppage, the necessity of frequent renewal, and the rapid oxidation of the wrought iron, were grave objections, and cast iron was used in the form of a rectangular casing of the whole length of the furnace, and filled with small cast-iron balls. In order to prevent the oxidation of the casing, its outer sides were grooved, to retain a refractory lining of a mixture of silicate of soda and fireclay; but this lining soon commenced to crack and flake off on continuous exposure to the flame. Further, the oxidation and expansion of the cast-iron balls produced fracture in the outer casing; in other respects this form of superheater gave highly satisfactory results.

The form of superheater now adopted consists of a cast-iron casing, rectangular in section, having a longitudinal division dividing the casing into two parts. The steam entering the lower division is compelled to traverse the whole length of the superheater twice before it can escape; to increase the heating surface, the cast-iron casing is filled up with broken pieces of fireclay of irregular size; the sides of the cast-iron casing are protected from actual contact with the flame by means of fireclay tiles. The superheater can be renewed without disturbing any part of the structure or cooling down the furnace, a great desideratum, as the latter operation is very detrimental to the condition of the furnace. The superheater is connected to the muffle by means of an expansion coil, which permits the superheater to expand and contract. It further serves as a pyrometer, as by the relative visible temperature of the coil, which can be visually examined by removing a portion of the loose coal ashes which cover it, the temperature of the steam entering the muffle can be ascertained.

A great difficulty was at first experienced in arranging a satisfactory rolling carriage, for carrying into and out of the muffle the articles to be oxidized; but the difficulty has been solved by an arrangement consisting of a cast or wrought iron table having equally distributed perforations over its entire surface, and having horizontal cast or wrought iron webs or ribs on its under side, which keep the differential rolling arrangements in position. This latter consists of a series of double rollers, their peripheries running in the channels formed on the under side of the table, and upon the false cast-iron base-plate forming the muffle floors. The rollers are held together by wrought-iron bars. By this arrangement, although there is no part of the rolling apparatus actually bolted, the carriage runs as freely and firmly at a temperature of bright red heat as when cold, and each part can easily be removed and renewed.

A point of importance to insure the success of the process is the arrangement of the articles on the table before treatment. If placed indiscriminately and carelessly upon each other, they may become distorted during the process. All articles of any great length should be laid perfectly level, and be evenly supported, with sufficient space to allow for expansion. This is easily accomplished by the form of cradle or frame used. This consists of a framework of wrought-iron bars. Loose T-irons, bent at the ends, so as to hang over the horizontal bars of the frame, are fixed in any position suitable for supporting uniformly and level the articles to be treated. The treating table is drawn in and out of the muffle by means of a crab-winch. When ornamental or other castings of great delicacy of form are treated, a sheet-iron cooling cover is lowered to receive the table as it is withdrawn from the muffle. This allows the castings, etc., to be very slowly cooled; but generally this cooling cover is not required, as the accumulated heat of the carriage and frame rarefies the air and prevents the castings from becoming cooled too rapidly.

After the articles to be treated are properly arranged on the table, the chain from the winch is attached to a portable handle, which is dropped into holes in the table. The muffle doors are then lifted, and the table is slowly and carefully drawn into the muffle. The doors are next lowered, and with a trowel the attendant lutes their edges with a mixture of loam and sand. Just before the articles are drawn into the muffle the steam is gradually turned through the superheater into the muffle. A pressure varying between one atmosphere and two atmospheres is all that is necessary, as great pressure only forces the steam too rapidly through the superheater. What is necessary, before the articles are placed in the muffle, is that a plenum of steam should be established, in order to prevent the influx of air into the muffle; the heat of combustion is then turned fully over it, and by withdrawing the damper is afterward directed on to the superheater, where it is compelled to pass under and over the latter by baffler walls. These also support the floor of the muffle, and act as accumulators of heat. After passing around the superheater, the products of combustion may be directed into a steam-generator. In the works of the Bower-Barff Rustless Iron Company at Southwark, it is intended that the waste heat shall, on its way to the chimney, be directed through the tubes of one of Cochrane's patent vertical multitubular boilers—a form of steam-generator very suitable for this purpose.

After the temperature of oxidation is attained in the

* From the selected papers of the *Proceedings of the Institution of Civil Engineers.*

† Molesworth's *Pocket-Book of Engineering Formulæ*, twenty-first edition, p. 33.

* *Journal of the Iron and Steel Institute*, 1877, pp. 456-460.

muffle, the flow of combustion is almost entirely directed immediately on to the superheater, by withdrawing the damper; only as much heat being allowed to pass round the muffle as will maintain the temperature of oxidation; the temperature of the muffle can be ascertained either by using a pyrometer, or visually, by withdrawing one of the movable sight-plugs provided in the doors. If the articles are covered with rust before they are treated, the rust must be reduced, immediately the temperature of oxidation is attained, by first shutting off the steam from the muffle, and turning into it instead carbon monoxide gas from the producers, by means of a valve and its connections. During this process a good pressure of CO gas must be maintained, otherwise there is a danger of the ingress of air into the muffle. After the process of deoxidation, which varies in time according to the extent of the rustiness of the article, the steam must be turned on carefully.

Another deoxidizing process is occasionally used, with very good results. The method is as follows: Oil is poured into a funnel, having a siphon bend, from which it passes into the muffle by a ½ inch gas pipe. In its passage through the latter the oil becomes decomposed and volatilized, and the hydrocarbon vapors, being prevented from escaping by the liquid seal of the oil siphon bend, are driven into the muffle, where they effectually convert the red rust Fe_2O_3 into the magnetic oxide Fe_3O_4. It is important, in order to prevent the possibility of the influx of air into the muffle, that a continuous and uniform pressure of steam should be maintained. The least admission of air will produce an imperfect and unstable coating of magnetic oxide. Generally, when air obtains ingress into the muffle, the articles are found to be covered with a film of oxide of a brilliant red color and having a lustrous appearance. When this occurs, the furnace should be at once examined, as it is a clear proof that air gets into the muffle somewhere.

Occasionally there may be a leakage, and air may enter in such small quantities as not to exhibit the phenomenon described, and such has been the case with one of the furnaces at St. Neots. The magnetic oxide coating, although apparently perfect, was, after a few times' exposure to oxidizing influences, found to exhibit incipient signs of red oxidation. On examination the muffle was found to have a fractured plate. In an externally heated muffle, like that of the Barff furnace, it is possible to regulate the temperature to a nicety, a feature of great importance when intricate and delicate articles of steel or wrought iron require oxidizing; but for heavy cast-iron articles external heating is very disadvantageous, both from the question of economy in the use of fuel and in the time required to heat the articles up to the temperature of oxidation. Hence the advantage for cast iron of the internal and direct heating features possessed by the Bower process. Another great advantage of the latter process is that the progress of oxidation can be readily and almost closely examined during one of the oxidizing operations. Through one of the sight-plugs in the muffler-door a lighted gas-rod is inserted, and by looking through one of the other adjacent sight-plugs, the exact character and progress of the oxidation can be clearly seen; hence the process is exactly reliable, and there need be no sense of uncertainty as to results.

By the Bower process a most effective coating of magnetic oxide can be obtained in from three to eight hours, according to the thickness, character, and size of the articles to be operated upon. In this process the rustier the articles are, the more effective and speedy is the process of oxidation. Old cast-iron water and gas pipes, that were so covered with rust as to be commercially valueless, have been converted into a condition more durable and valuable than they were when first withdrawn from the moulder's sand. The magnetic oxide coating produced by the Bower furnace, on the surface of the roughest castings, is smooth to the touch, and has almost the finished appearance of enamel. The smoothness of the surface is, however, more apparent than real, as by microscopical examination the surface presents a granular appearance. If occasionally the articles are slightly warped, they can, by a judicious re-heating, accompanied by the application of pressure, produced by weights, etc., be brought back to their original shape.

A French chemist, Mr. Dode, discovered, some years ago, a singularly cheap and beautiful process for depositing from their salts the noble metals upon the surface of a special description of enamel, which was fused upon the surface of iron and steel articles; but it was discovered that corrosion unfortunately set up under the coating of enamel, and eventually threw it off. It was decided to try Mr. Dode's process upon the magnetic oxide coating as produced by the Bower process, and the experiments proved a decided success. The Societe Francaise d'Inoxidation et de Platinage, though proprietors of Mr. Dode's patent, also purchased the Continental patents of Mr. Bower and eventually those of Mr. Barff as well. By a special arrangement of the furnaces, Mr. Roque, the engineer of the Societe Francaise, is able to treat articles of a very considerable length.

The color of the magnetic oxide coating as it emerges from the furnace is a light tint of French gray, which can be made to have a silvery, lustrous appearance by merely filling the muffle with the vapors of volatilized liquid hydrocarbon, produced from oil poured into a special siphon formed as already described. The color of French gray will be retained by the magnetic oxide as long as it is free from contact with liquid grease, oil, or other hydrocarbons. The least touch of any of these instantly converts the light French gray color into one of a bluish-black appearance, which no energy of washing or rubbing will remove. But of course the grease or oil is volatilized on exposure to heat, leaving the oxide with its original color. All articles that are likely to be handled should be oiled. Mineral oil is the most suitable; and as the coating of magnetic oxide rapidly absorbs the oil, the least application is sufficient; and after the superfluous oil has been thoroughly rubbed off, the oxide presents a dark and polished appearance, which to some people is preferable to the delicate natural color of the oxide. A very pretty effect may be obtained, upon ornamental castings, by oiling the minor or subordinate parts of the ornament, leaving the prominent or main parts untouched. In the preliminary experiments with the magnetic oxide it was noticed that if any foreign metal was rubbed upon its surface, part of the latter was deposited or left on the former, a property not possessed, as far as the author knows, by any other oxide; this remarkable discovery led Mr. Bower to make a series of experiments with various descriptions of metallic brushes with wires of all the noble metals, as well as of various alloys; in all cases the results were the same, and oxidized castings can be gilded, platinized, or bronzed, etc., most charmingly, cheaply, and quickly by merely rubbing over the surface of the magnetic oxide coating with metallic brushes with bristles of any description of metallic wire other than iron. In order to permanently fix the gilt, the gilded castings are exposed to very moderate temperature—say 600° Fahr.—for about thirty minutes.

As already mentioned, the Societe Francaise d'Inoxidation et de Platinage utilizes the magnetic coating as a base for receiving their special enamel. Upon this enamel, or even direct upon the magnetic oxide coating, gold, silver, platinum, etc., can be permanently deposited by mixing the chlorides of these metals with certain essential oils, and then placing the iron articles, washed with the metallic chlorides, in the furnace for a short time. The novel feature of both the attrition and Mr. Dode's principle of gilding, platinizing, etc., is that the same iron article can be ornamented with various metals, in conjunction, if desired, with other coatings, such as variously colored enamels. When the oxidized castings require to be enameled, no costly preliminary process of annealing is necessary, and the enamel can be deposited direct upon the coating of magnetic oxide. The strength of constructional ironwork is practically unaltered by the Bower-Barff process.

The following may be taken as a fairly accurate list of the thicknesses of the magnetic oxide coatings required for various descriptions of iron:

	Inch.
Light sheet iron, a thickness of	0·0035
Light wrought iron, a thickness of	0·0104
Heavy wrought iron (such as tubes), a thickness of	0·0188
Light cast iron (such as tubes), a thickness of	0·0183
Heavy cast iron (such as tubes), a thickness of	0·0200

As the magnetic oxide is not very pliable, it is not suited for articles which have to be bent after their treatment, and if struck very violently with another hard metallic body, it is liable to chip off at the point of contact; but when the process is properly accomplished, the oxide coating will withstand all ordinary concussions. If a piece of the oxide coating is, however, removed, the corrosion which may set up in the denuded portion will be strictly local, and will not burrow under the coating remaining intact. If the magnetic oxide is perfectly formed, it will resist all ordinary corrosive influences; but it is affected by contact with strong corrosive acids, although a piece of oxidized cast iron has been found to resist for a considerable period the action of dilute acids, such as urine; but the author would not advise its adoption for apparatus used in the chemical industries, except in the laboratory, where it has been utilized with success for preserving iron tripods, Florence flask-holders etc. Fe_3O_4 represents the chemical equivalents forming magnetic oxide, hence the relative equivalent weights will be as follows:

3 (56) = 168, or 72·41 per cent. Fe.
4 (16) = 64, or 27·59 per cent. O.

It is magnetic, as its name implies, and has a specific gravity of from 4·98 to 5·20. To test the character of the magnetic oxide coating, the oxidized articles are placed upon a damp soil, say for two hours, and are then allowed to become dry in the open air. These alternate processes of exposing the oxidized articles to wet and dry periods are continued for several days, and if the coating is imperfect, a few days' exposure to the test described will bring its imperfections to light. If the oxide coating resists satisfactorily the test experiment for a period of five or six days, it is perfect and durable. One of the greatest advantages possessed by the Bower-Barff process is the completeness with which the oxidation is effected upon every part, however intricate it may be, of the metallic surface of the articles submitted to it; hence its applicability to hollow cylinders, pipes, etc., of intricate shape. Owing to the increased size of the articles submitted to the process by the addition of solid oxygen, it is necessary that all parts which have to be fitted together, such as screws, bolts, etc., should be slightly run down or otherwise decreased in size to allow for this addition. The magnetic oxide coating, giving as it does a finished appearance and smoothness to the iron, the latter can be painted, if desired, far more easily than if it was unoxidized, and the painted surface will be far more durable. Ordinary oil-paint, when applied to unoxidized iron, has only a comparatively short life, arising from the fact that the moisture of the condensed aqueous vapor on its surface eventually permeates through the paint, setting up corrosive action, which ultimately throws it off; hence the importance of having iron articles oxidized or Bower-Barffed, even if it is desired that they should be painted as well.

It will no doubt be obvious that the cost of oxidizing by the Bower or Barff process—or, to use a more abbreviated expression, the cost of Bower-Barffing—varies considerably; for example, one thousand small articles may be treated at the same time, and in the same cubical space, that might be occupied by a single large article; but when the latter is hollow, and when possible, the hollow space may be filled up with smaller articles. Mr. Flamache, engineer for the Belgian state railways, who was sent over by the Belgian Works Department to report on the process, found the cost, exclusive of royalty, to be as follows: 7½ francs per 1,000 kilogrammes by weight, or ¾ of a centime per kilogramme; and superficially, ⅜ of a centime per decimeter cube. In the Bower furnace of the Societe Francaise at Grenelle, the weight of objects treated in twenty-four hours varies from 47 to 85 cwt., with an expenditure of fuel of from 10 to 12 cwt. of good slack coal. In the Barff furnace, of the same form, the weight of objects that can be treated in twenty-four hours varies from 47 to 106 cwt., with an expenditure of fuel of from 15½ to 17½ cwt. For a Barff furnace having a muffle capacity equal to 124 cubic feet, the quantity of water evaporated per hour to supply the muffle with superheated steam is equal to from eight to ten gallons. One attendant is required for every two furnaces in ordinary working; but auxiliary labor is required when loading or unloading.

The following is a list, necessarily limited, of articles especially adapted for receiving the coating of magnetic oxide:

Cast Iron.—Architectural ironwork; horticultural ironwork; sanitary appliances; engineering ironwork, such as water-mains, gas-mains, roof and bridge castings, etc.

Wrought and Sheet Iron; Untempered Steel.—Water, gas, and pneumatic tubes; cramps, roofing tiles, and generally all ironwork which will not be liable to rough usage, and not require bending or riveting after treatment.

It will probably be seen that the Bower-Barff process is applicable to those articles to which galvanizing is more or less inapplicable; and the former process therefore serves as a useful auxiliary to that well-known and excellent process of preserving iron by means of a coating of zinc. For the Bower furnaces in New York, in place of bituminous coal, anthracite is used in the producers, in conjunction with gas from petroleum oil. The latter is allowed to trickle slowly through the coal-charging hopper of the central producer, where, falling upon the anthracite incandescent fuel, it becomes volatilized, and produces a very powerful reducing or deoxidizing gas. In order to prevent the oil from igniting and firing back, it is led by a pipe from a considerable distance. In the New York Bower furnaces, equal periods of both oxidation and deoxidation, of a duration of fifteen minutes each, are found to give very satisfactory results. In the same Bower furnaces Mr. A. S. Bower has been successful in carrying out the Barff process for heavy wrought-iron articles by the following method: After the wrought iron articles have been heated by direct combustion inside the muffle apparatus to the temperature of oxidation, the gas and air are shut off from the muffle; the chimney damper is closed, and steam is turned into the recuperator tubes, and in passing through them toward the muffle becomes highly heated. The steam is kept on continually until the temperature of the articles begins sensibly to decrease, when it is shut off, and the gas and air are turned on (in such relative proportions as not to affect the character of the oxide coating), until the proper temperature is again regained; and the same operations of shutting off gas and air, etc., and turning on steam, are repeated as often as required to effect a proper thickness of the oxide coating.

THE SPECTROSCOPIC EXAMINATION OF THE VAPORS EVOLVED ON HEATING IRON, ETC., AT ATMOSPHERIC PRESSURE.

By JOHN PARRY, Ebbw Vale.

METALLURGISTS favored with opportunities of observing the behavior of metals while being heated or fused are of opinion that the fumes usually seen are due to the volatilization of the metal itself, or of some more volatile constituent.

In casting alloys of the more fusible metals, this dissociation or volatilization is an accepted fact, and is usually considered when adjusting the proportions of the constituents. Alloys of the more infusible metals, such as iron, manganese, nickel, cobalt, etc., have not been studied; but those who have observed the behavior of the crude iron and steel while being fused, or otherwise manipulated at high temperatures, have noted that, in addition to the well-known evolution of gas, fumes are given off, which has led to the inference that, as before stated, some more volatile constituent is being evolved; and Professor Ledebur asserts that as iron is being volatilized the chemical composition of the metal may be changed, presumably within certain narrow limits. It may be that crude iron is slowly dissociated, and certainly at the high temperature of the Bessemer process iron is volatilized, and may be seen far above the mouth of the converter, forming a red cloud, quite unlike ordinary smoke or vapor.

The spectroscopic examination of the flames issuing from blast and other furnaces shows only continuous spectra, with but few lines, very similar to the spectrum of the ordinary Bunsen flame, with the exception of the Bessemer flame, which gives the carbon spectrum, together with (according to some observers) that of manganese.

I have, however, found that many of the metals are volatilized at a comparatively low temperature, but give only continuous spectra when examined in the flame. The vapor requires the intense heat of the electric spark to be passed through it to insure complete dissociation, and consequent production of the usual line spectra. (A list of metals tested is attached hereto.)

Spiegeleisen fused in a crucible evolved a fume in which I detected zinc, copper, manganese, calcium, and, with less certainty, magnesium.

Bessemer pig-iron, similarly treated, gave copper, manganese, calcium, either lead or arsenic, as well as gas burning with a flame resembling that of carbonic acid.

Bessemer pig-iron burnt in a stream of oxygen at a dull red heat gave copper, manganese, etc., as before, but more intensely; also a great number of lines which appear to be derived from iron. This spectrum requires careful study, and, when developed, may throw some light on the reactions occurring during the Bessemer blow.

Spanish iron ore reduced in a crucible with charcoal, at a heat sufficient to form a button of fused metal, evolved zinc, copper, and manganese.

It is therefore probable that matter may be evolved during the ordinary heating processes in the manufacture of iron and steel, as previously explained, but giving no visible indications of the fact, in consequence of the heat being sufficient only to volatilize without effecting dissociation.

With my present limited experience, I am of opinion that the actual quantity of matter evolved from iron, steel, etc., is very small, and not at all likely to affect the quality of the coarser kinds of iron and steel, although it may be otherwise when a material of good quality and great purity is required.

The germ of the foregoing is to be found in the recent work of spectroscopists, more especially of Mr. Lockyer, who, in his "Studies in Spectrum Analysis"

—a volume abounding with suggestions which should, in my opinion, be carefully studied by those practically engaged in the iron manufacture—says: "Depend upon it, that as spectroscopy becomes the daily work of iron founders and the like, it will be found to be bristling with scientific truth which may be used in these practical applications."

Note.—Spanish iron ore evaporated to dryness with hydrochloric acid. The dried chlorides were carefully and gradually heated in the blowpipe, and copper, zinc, calcium, barium, lead, silver, and manganese lines successively detected in volatilized chlorides. At the highest obtainable heat, iron lines are seen.

The impure ferric chlorides, obtained by digesting steel or iron in hydrochloric acid and evaporating to dryness, heated as above, show: first, copper and calcium; second, manganese; next, with less certainty, chromium and magnesium. On increasing the heat, the iron spectrum is vividly seen.

Steel or iron filings, mixed with ammonium chloride, and heated also, give the foregoing series of spectra, which last longer, and may be repeated by successive additions of the chloride.

Very fine spectra of sulphur and phosphorus may be obtained by slightly heating either on a moderately hot plate of iron, placed just below the spark from the coil.

Notes on the Volatility of the Metals Heated in Crucibles.—Fletcher's "Injector Blowpipe" used.

Thallium.—Very volatile. Seen in flame and spark above.
Arsenic.—Very volatile. Seen in spark only.
Copper.—Very volatile. Volatilized from most metals in flame and spark.
Cadmium.—Easily volatilized. Seen in spark only.
Zinc.—Easily volatilized. Seen in spark only.
Bismuth.—Volatilized at highest red heat. Seen in spark only.
Antimony.—Easily volatilized. Seen in spark only.
Potassium.—Easily volatilized. In flame and spark.
Sodium.—Easily volatilized. In flame and spark.
Tin.—Volatilized at highest temperature of blowpipe. Spark only.
Lead.—Volatilized at lower temperature than tin. Spark only.
Silver.—Not volatile. Copper spectrum seen. Spark only.
Gold.—Not volatile. Copper spectrum seen. Spark only.
Chromium.—Not volatile. Copper spectrum seen. Spark only.
Manganese.—Volatilized with difficulty. Spark only.
Aluminum.—Volatile. Spark only.
Selenium.—Very volatile. Spectra require further study.
Tellurium.—Very volatile. Spectra require further study.
Phosphorus.—Easily volatilized on hot plate. Good spark spectrum.
Sulphur.—Easily volatilized on hot plate. Good spark spectrum.

Notes of Experiments on the Spark Spectra of the Chlorides of the Metals and Alkalies Volatilized at Atmospheric Pressure.

The chlorides of lithium, strontium, copper, and calcium are volatile in the flame of an ordinary alcohol lamp, showing the characteristic spectral lines in the spark about one inch above the flame.

Zinc, barium, copper, and magnesium chlorides are also faintly seen. Query about arsenic? Filter-paper moistened with zinc chloride and placed in the alcoholic flame gave the line W. L. 4809.

Steel filings, mixed with ammonium chloride and heated—copper and manganese first appear, next calcium (zinc?), next iron spectra; after heating thirty minutes only, one copper and two manganese lines are seen. Iron lines nearly gone; calcium seen. Further heated thirty minutes, only calcium; traces of copper flashing out.

Spiegeleisen as above; in addition, magnesium seen; brighter spectrum throughout.

Copper chloride mixed with ammonium chloride and heated with spirit-lamp in a glass tube twenty inches long—copper distinctly seen in the spark at the top of the tube.

Impure steel chlorides, as above, heated in glass tube four inches long, spark at top—calcium first seen, copper, next manganese group. After heating some time, only calcium and copper were visible.

Ordinary nickel, cobalt, bismuth, tin, and antimony show copper spectrum when heated. All metals hitherto tested evolve copper.

Query zinc in steel?

Query magnesium in spiegel? Only first line of magnesium seen on edge of nitrogen line, W. L. 5712.

Compared this line with magnesium, by clamping cross wires down on it; magnesium line distinctly seen on edge of nitrogen, W. L. 5712.—*Chem. News.*

THE BLANCHARD FURNACE AND STEAM GENERATOR.*

YOUR correspondent had the privilege the other day of making a visit to the Blanchard furnace and steam generator now being experimented on at the works of Wallace & Sons, Ansonia, Conn.

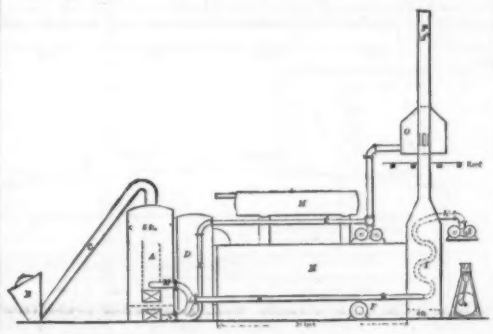
This furnace and generator, it is claimed by the inventor, will revolutionize steam engineering, inasmuch as it will generate steam for a small fraction of the fuel now used. Quite a large party visited the works at the time, including two well known general managers of Bessemer steel works, a prominent blast furnace engineer and contractor, a blast furnace superintendent, and a proprietor of an iron works, all of whom are prominent members of the American Institute of Mining Engineers; also a New York capitalist, and two or three others whose name your correspondent did not learn.

Arriving at Ansonia about 10:30 in the morning, the party somewhat surprised the inventor of the furnace, as only one or two gentlemen were expected instead of so large a party, and he claimed that his invention was not in just such a condition as he would like to have it before making it public. However, after some parley, he courteously received the party, promised to put the furnace in running order, and exhibit it after dinner.

In the afternoon about an hour was spent in visiting the apparatus, and a partial explanation was made by Dr. Blanchard. He promises to give a complete exposition of it in a book which he will shortly publish. Your correspondent, however, exercising his liberty as a journalist to get ahead of his competitors by making the first publication of the invention as it appears to an outsider, will try to give your readers something of an idea what the thing is like, although the shortness of the visit, and the confusion incident upon a large crowd of men visiting such a novel and complicated invention, would prevent his description having the merit of scientific accuracy. The visitors crawled all over and around the apparatus, treading upon each others' heels, and importuning Dr. Blanchard with all sorts of questions; some he answered to their satisfaction, but others, for reasons of his own, he declined to answer.

The diagram herewith presented is made from memory of the visit, no notes and sketches of any kind being taken by any of the visitors on the spot. It is, of course, exceedingly rough and inaccurate, but probably is sufficiently clear for readers to form an idea of what the invention consists.

A is a gas producer incased in a cylindrical shell, like the Wilson; it has 13 square feet of grate surface, upon which coal is carried about 18 inches deep. B is a coal hopper, and C a conveyer, or elevator, by which coal is carried from the hopper to the gas producer; the upper portion of the gas producer is filled with fire-brick arranged in a manner which is not explained. D is a chamber between the gas producer and the boiler. E is the boiler, inclosed in a rectangular room surrounded with cast-iron plates. Nothing of the engineering structure of the boiler could be seen, but it was explained to be a water-tube boiler built of copper tubes, in which a forced circulation was obtained by means of a turbine, F, driven by a belt from the engine, G. H is a steam drum, or a steam separator, which serves to dry the steam. I is a stack into which the products of combustion pass. J is a Root blower, which delivers cold air into a pipe, K K, which passes through the stack, I, in circuitous direction to absorb the waste heat; the hot blast passing through the pipe, K, is divided at the valve, L, into two portions, one of which enters the gas producer under the grate bars, and the other above the coal. The stack, I, is continued up into the chamber,



BLANCHARD FURNACE AND GENERATOR.

O, from which a portion of the products of combustion are drawn by the Root blower into the pipe, R, which joins the pipe, N, and thus delivers part of the products of combustion under the grate bar, the remainder escaping through the pipe, P.

As explained by Dr. Blanchard, the boiler, E, contained about 5,000 square feet of heating surface; the blower, J, is said to deliver 5,000 cubic feet of air per minute. The products of combustion, after passing out of the coldest end of the boiler and being further cooled by the air flowing through the pipe, K, are discharged into the chamber, O, where they separate according to their specific gravity into carbonic acid and nitrogen, the carbonic acid being drawn off at the bottom by the Root blower through the pipe, R, under the grate bars.

The copper works of Wallace & Sons are at present running two large Babcock & Wilcox boilers of 250 horse power each, and one duplex water-tube boiler of about the same capacity. Each of these is said to burn six tons of coal in ten hours. When the Blanchard furnace and steam generator is running, using only one pound of coal per minute, one of these boilers may be shut off; but Dr. Blanchard expects shortly, when he gets his apparatus into proper running order, that it will develop not less than 3,000 horse power. So much for the description as far as your correspondent could make it out from the fragmentary conversations carried on during the visit.

To show a little more clearly the subject matter, a few of the statements made by Dr. Blanchard and some of his assertions given in answer to questions are quoted below:

Question. Why do you have a tight lid on the coal hopper?

Answer. Because, if everything was not tightly closed, the blast would blow the coal out of the hopper.

Q. What saving do you claim over other boilers?

A. The best boiler now made does not utilize over 10 per cent. of the heating value of the fuel, owing to imperfect oxidation. My furnace makes perfect combustion—not only burns up the coal, but the ashes. You see there are practically no ashes under the grate bars.

Q. How many pounds of water does your apparatus evaporate?

A. That is the great mistake made by all boiler-makers in talking about evaporative tests. The evaporative tests prove nothing. The proper way to demonstrate the efficiency of an apparatus would be to show what work it will do by running a works as we are doing.

Q. What is the chief element of your apparatus?

A. The gas producer; it develops all the latent energy in the coal.

Q. Can your gas producer be applied to any boiler?

A. No; because the heat developed is so intense that no ordinary boiler would stand it; it requires a boiler made as I made it, of copper tubes, to stand the intense heat of about 500 degrees.

Q. What is the temperature of the escaping gases?

A. You can put your hand in the chimney, and see for yourself; it is only about 150 degrees. (This appeared to be the temperature of the gases in the chamber, O, as tested by the hand.)

Q. What is the size of the flue in the brick work in the gas producer above the fire?

A. Eighteen inches diameter.

Q. What effect does the carbonic acid have going under the grate bars?

A. It enables one to regulate the temperature of the fire, and preserves the grate bars from burning out.

Q. The apparatus as you have it would cost about $10,000, would it not?

A. That is about the figure.

Q. If your boiler then replaces only one of the Babcock & Wilcox boilers, that makes it rather expensive in first cost, does it not?

A. Yes, if that were all it could do; but you would not call it expensive if it develops 3,000 horse power, which it will do.

Q. How much saving do you claim over other boilers?

A. As a boiler is now built, mine is forty times more economical than others.

Q. Then, if other boilers evaporate eight pounds of water to a pound of coal, yours would evaporate 320 pounds, would it not?

A. I decline to be led into any scientific discussion. I am not prepared at present to explain the whole thing; wait until my book comes out, and you will see it all there.

The above is a fair sample of the conversation that was carried on, first by one and then by another of the visitors. We saw no signs of any scales for weighing coal or tank of water, meters for measuring the water used, or any means of measuring the amount of steam that was made, as the steam pipe from this generator was connected directly to the main steam pipe, which was also led to the other boilers.

From the number of strokes to the feed pump, it might be estimated that the apparatus was developing 500 H. P., provided there was no leak to the valves of the pump. The whole apparatus was well inclosed by felting, so that there was very little radiation.

The apparatus is all exceedingly well built. There are several fine details of mechanism about it, and your correspondent never saw a better designed experimental plant for any purpose; indeed, money seems to have been spent upon it lavishly. There are apparently several good points about it: first, automatic stoking; second, conversion of the fuel into gas; third, burning of this gas by hot air; fourth, economizing the products of combustion by utilizing them to heat the water. All of these might be applied to any boiler system. As to the advisability of carrying carbonic acid gas from the chimney back under the grate bars, and as to the possibility of separating the carbonic acid from the nitrogen in the chamber, O, these are matters for scientific discussion.

As to the statement made by Dr. Blanchard that other boilers will not utilize 10 per cent. of the heating efficiency of the coal, that will be disputed by the best authorities on steam engineering, who admit that from 70 to 75 per cent. can be utilized in boilers of the best modern construction.

As to the possibility of developing 250 horse power from one pound of coal per minute, and of the burning of coal without making any ashes, these are statements that will not be believed by any of our old school engineers until it is proved to them by the evidence of their senses; but when this statement is made to those who believe in Dr. Blanchard's furnace, they reply that the same statement was made of the Giffard injector when it was invented, and of the modern locomotive, steamship, electric light, telephone, and other inventions.

To your correspondent it seems that Dr. Blanchard's furnace may possibly be a success when Mr. Edison solves the problem of generating electricity directly from coal without the intervention of a steam boiler; when the metal aluminum is made from clay as cheaply as iron is made from the ore, and when flying machines made of aluminum are our means of locomotion. But of course your correspondent's opinion on this subject is worth no more than that of any one else, and he looks anxiously forward to Dr. Blanchard's book for a complete explanation of his system and exposition of its grand possibilities.—*Amer. Engineer.*

THE FORTH BRIDGE.

ON MANIPULATING THE MATERIAL, AND BUILDING, AND DRILLING THE GREAT TUBES OF THE FORTH BRIDGE.*

By MR. ANDREW S. BIGGART.

THE Forth Bridge has on various occasions formed a theme of deservedly widespread interest, and the general character of the undertaking is more or less familiar to engineers. A comprehensive view of the subject, and of the numerous engineering questions involved, has also been lately so ably given by Mr. Baker that the writer purposes in this paper to at once pass on to examine some of the later details of the manufacture of the superstructure, such as that of the work in connection with the great tubes. One of the well-known features in the design of this undertaking demands that struts of hitherto unequaled length, and capabilities for resisting thrust, be employed. The form which best fulfills these conditions is the tubular. As well nigh six miles of tubes are required in the completed bridge, it at once becomes evident that the construction of them could only be effected within a reasonable time by the adoption of special plant. Owing also to their novelty of form and great size, no machinery was in existence capable of dealing with such work. On account of this, and for various other reasons, Mr. Arrol determined to design special plant for the whole work, the description of a part of which, and the mode of working the same, can be but scantily treated of in this paper. The struts required are of various dimensions, ranging from that of the largest, which is 12 feet diameter, to that of the smallest, which is only 3 feet. The description of the former will be considered in this paper, although all are very much alike in design.

Fig. 6, next page, shows the cross section of one of the 12 foot horizontal tubes between the piers. It consists of ten plates and ten longitudinal H beams, stiffened at intervals of 8 feet by means of the circular girders

* An unofficial meeting of mining and mechanical engineers,

* Institution of Engineers and Shipbuilders, in Scotland.—*The Engineer.*

MACHINERY USED IN CONSTRUCTING THE FORTH BRIDGE.

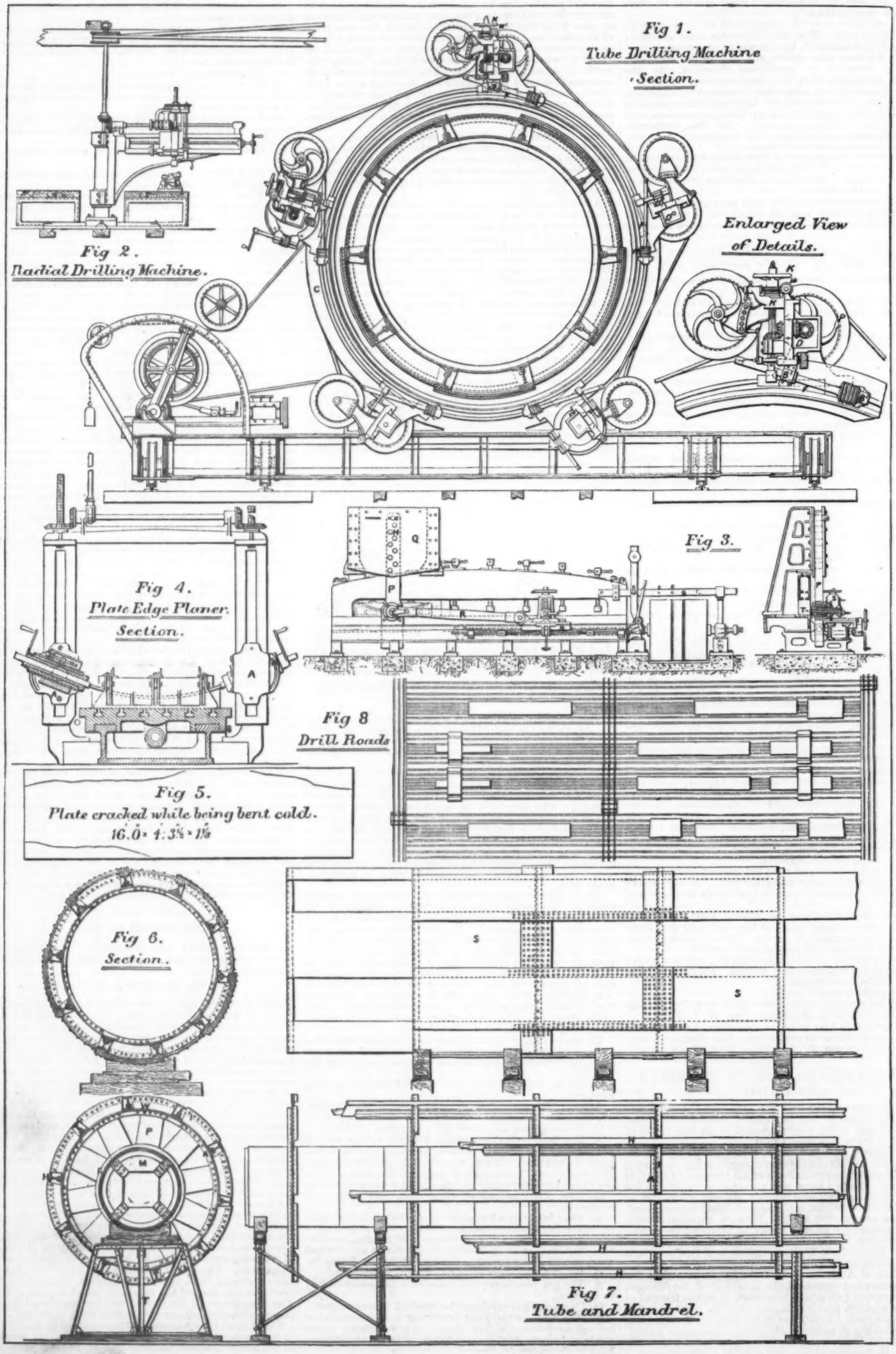


Fig 1.
Tube Drilling Machine
Section.

Enlarged View
of Details.

Fig 2.
Radial Drilling Machine.

Fig 3.

Fig 4.
Plate Edge Planer.
Section.

Fig 8
Drill Roads

Fig 5.
Plate cracked while being bent cold.
16.0 × 4.3¾ × 1⅛

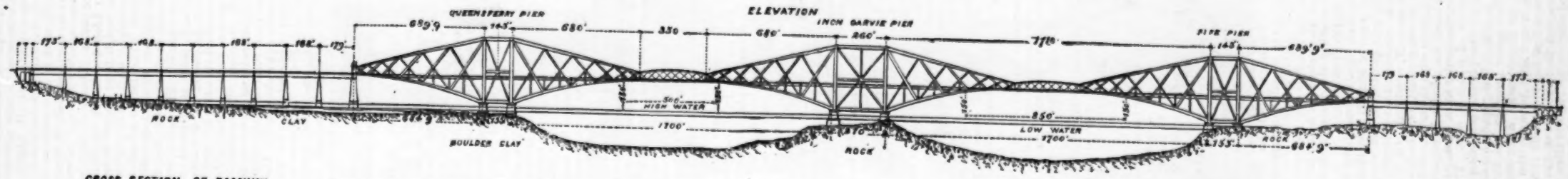
Fig 6.
Section.

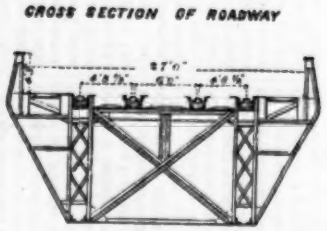
Fig 7.
Tube and Mandrel.

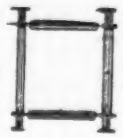
SCIENTIFIC AMERICAN SUPPLEMENT, No. 478.

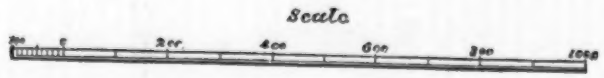
FEBRUARY 28, 1885.

MACHINERY USED IN CONSTRUCTING THE FORTH BRIDGE.









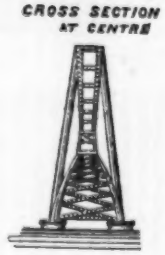


Fig. 14 SIDE ELEVATION.

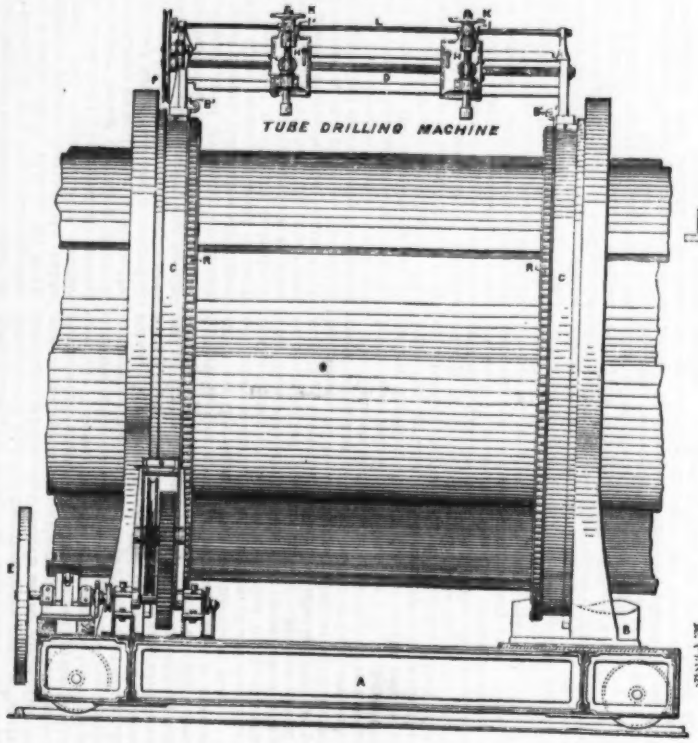
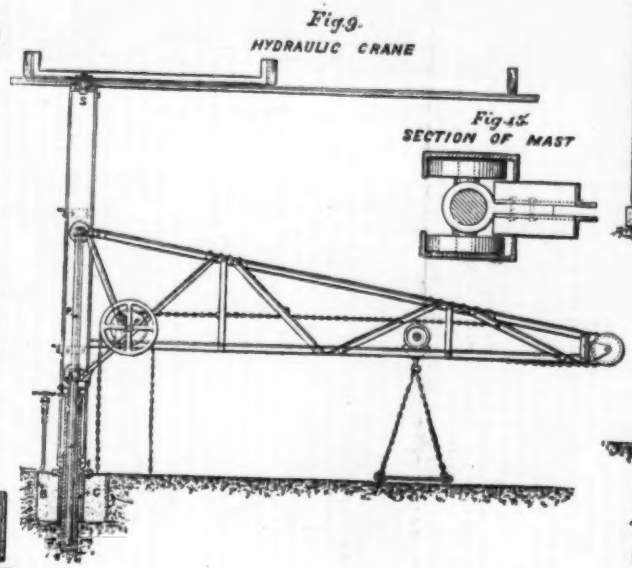
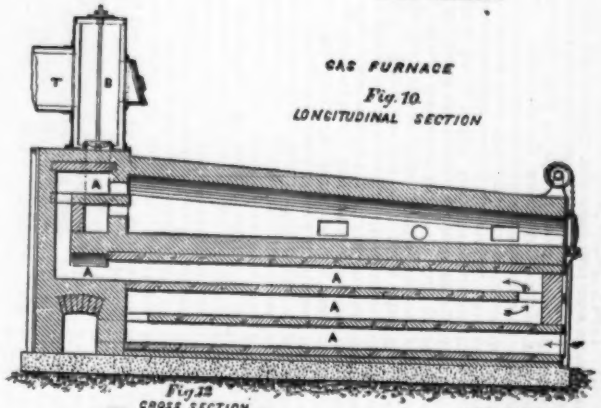
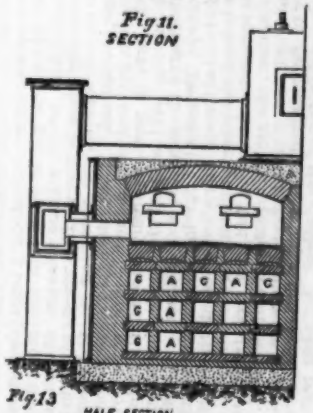
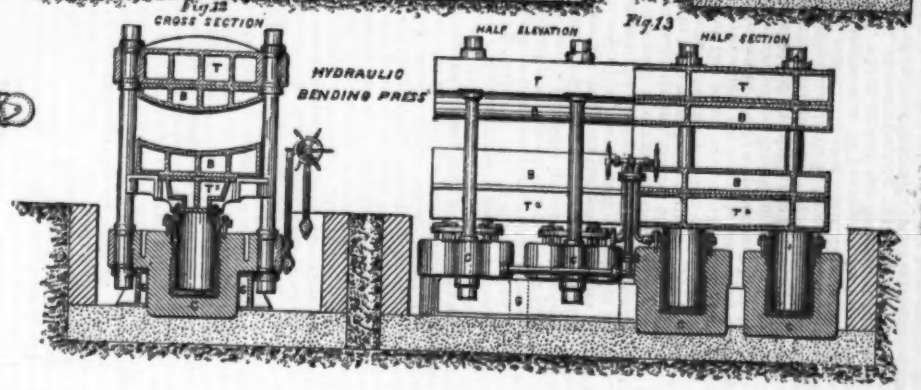


Fig. 9.
HYDRAULIC CRANE









shown in elevation. The girders, again, are made up of diaphragm plates, connected to inner and outer angles, the former being riveted to the H beams, while the latter are similarly fixed to the tube plates.

The work to be performed is somewhat as follows: The first and, for a time, the most difficult operation—owing to causes to be hereafter referred to—was the curving of the heavy plates. These, it may be mentioned, are 16 feet by 4 feet 4 inches by 1⅛ inches and 1¼ inches thick, and weigh from about 28 hundredweight to 32 hundredweight each. The method now adopted is to bend them while hot in a large hydraulic press, from which they are removed, and allowed to cool slowly. When cold, they are again placed in the press, and straightened finally. The edges and ends are then planed, and each plate is weighed, marked, and laid aside, ready to be placed on the tube when required. The longitudinal H beams are made up of a deep webbed tee and two angles, being partly drilled through these before erection. The circular girders are also partly drilled before being placed on the mandrel. These different parts form the main tube proper, leaving out the connections to skewbacks, the girder fixtures, tees, and other minor details, with which it is not at present intended to deal. The tubes are built round about a mandrel, being supported therefrom by temporary connections, and drilled through the various parts, while in the exact form they are intended to be when finally erected. Fig. 7.

This hasty sketch of the different steps of the work required to be executed will enable the details to be more clearly followed.

The plates are heated in gas furnaces, of the style shown in Fig. 10. The producer is close at hand, and from it the gas is led along the tube, T, to the box, B, and thence distributed to the different furnaces by means of other tubes. The gas is admitted at the side as well as the back of each furnace. This, by the way, was an afterthought, to enable the plate to be more evenly heated than when the gas was admitted at the back only, and it turned out a decided improvement. The escaping gases pass off through the flues, G, which are highly heated thereby, and these in turn give a part of their heat to the incoming air, which is then passing along the flues, A, on its way to the open furnace. The plates to be curved are heated to a dull red, after which they are withdrawn from the furnace by means of a hydraulic ram. To the end of the chain from the ram is attached a pair of tongs, made so that the greater the pull required, the grip is the firmer. The plate is withdrawn from the furnace on rollers, and run over a table into the hydraulic bending press, shown by Figs. 12 and 13. A pressure of 800 tons is now applied while the plate is between a set of convex and concave blocks of the form necessary to bring it to the proper curvature. Almost immediately on the blocks being separated, the plate is seen to be undergoing a change of form, and this so quickly that it is quite perceptible to the eye. Sometimes the convexity becomes greater, while at other times it is the reverse. In all cases the plate warps longitudinally, this taking place principally at the ends. The distortions are most irregular and inexplicable, a plate seemingly under exactly the same conditions assuming a totally different form, nay, perhaps the very reverse of that taken by the immediately preceding one. On being removed and allowed to cool, the plates gradually become in almost every case somewhat better, but scarcely ever sufficiently so to be suitable for the purpose for which they are intended. Many methods were suggested, and tried, to overcome this warping of the plates; thus, for instance, the edges were covered up, thereby allowing them to cool more from the center; another mode was to reheat, and give them a second squeeze; yet another was to allow them to cool partly, lying on a series of iron rollers, set to the true form the plate should take. These and others gave only very varying success. The plan finally adopted was to curve a quantity at a time, laying each plate, as it left the press, on the top of the immediately preceding one, with a layer of ashes between, and allow them to cool in piles of convenient size. When cold, each plate is again placed in the press, and straightened by means of repeated squeezes, strips of thin iron being placed above and under the points necessary to be brought to the true form. This answers the purpose admirably, and is the only method now in vogue.

A somewhat striking incident happened during these preliminary trials. It arose out of an attempt to bend one of the 1⅛ in. thick plates while cold. During this process the plate cracked in several places, although the curve was only equal to that of a circle with a 6 ft. radius. Samples of bending and tensile tests were cut off, and showed the plate to be of remarkably good material, and quite up to the specified quality, Fig. 5. Mr. Arrol attributed the failure to unequal cooling at the steel works, and this is borne out by the fact that different parts of the same plate are not uniformly easy or difficult to cut, but both these experiences are often found in a single plate. Mr. Baker thought the failure of the plate to stand the bending was due to the fact that its edges and ends were not planed, but in the state they were in when they left the shears at the works. He had made a series of experiments with sheared and planed plates, and from the results obtained arrived at this conclusion. Annealing removes satisfactorily both these objections, and in this lies the great benefit of bending the plates while hot, and allowing them to cool as described.

The hydraulic press, Figs. 12 and 13, for bending the plates consists of a set of four 24 in. cylinders, C, resting on two cast iron girders, G, and supporting, by means of two 7 in. wrought iron columns, from each cylinder, a fixed table, T, overhead. On the top of the rams is placed another table, T', which is raised and lowered in conjunction with the rams. Between these two tables are placed the blocks, B, required to bend the plates to their particular form, equal in this case to a curve the radius of which is 6 ft. The pressure brought to bear on the plates while being stamped is about 800 tons, provision being made for doubling this if necessary. The lower pressure has thus far been found sufficient for all purposes. After bending one of the first plates, it was kept between the upper and lower blocks for a few minutes while it was yet hot. The consequence was that the side of the block next the plate heated much more rapidly than the other or remote side. This induced a very heavy strain on the metal, so much so that it broke the upper one completely through, at the same time giving a report somewhat resembling that of the discharge of a pistol. The plates, after having been brought to their true form, as already described, are passed on to a large planing machine, as shown at Fig. 4, to be there planed on both sides. This is an ordinary planer, having the table driven by a 6 in. screw, but supplied with double cheeks, between which, on each side, are fixed the special tool-boxes, A A. The plate being operated upon is placed on cast iron curved blocks and held down to the table by means of bolts and draw washers, arranged so that they can be either quickly tightened up or loosened at will. Both tools cut simultaneously, and as the plate is being traveled backward as well as forward, they are fed into their work, and reversed, by hand. When the sides have been planed, the plates are placed in another machine, Fig. 3, to be there planed on both ends. They are here supported from, and held down to, the table at one end, in a manner similar to that adopted for the former machine, while at the other they are fixed by means of screws through the beam overhead. Wedges are also driven in lightly at the sides, to prevent the plate being shifted sideways by the action of the tool while cutting. The tool-box and tool, T, are carried in a pendulum, P, receiving its motion from the traveling saddle, S, by means of the connecting rod, R. Here also the tool is fed, and reversed, by hand. The pendulum, P, and plates, Q, have a series of holes, H, each of which in its turn will be made a new swinging center, to enable the tool to sweep the ends of the plates for the various sizes of tubes. After one end of a plate has been planed, it is reversed, and the finished end butted against a cast iron face plate, set parallel to the plane of motion of the cutting edge of the tool, thus making the two ends of each plate truly parallel, and thereby securing accuracy at the tube joints. Being now finished, each plate is weighed, marked, and placed on the pile with the nearest corresponding weight, ready to be removed and built on the tubes when required.

In the shops the handling of these plates, as well as the rest of the heavier parts of the structure, is done almost wholly by hydraulic cranes, of the style shown in Fig. 9. In the ground there is placed a cast iron box, B, which carries the cylinder, A. This, again, carries a mast consisting of two channels, having a hollow turned casting, H, at the bottom and a solid one, S, at the top. In the center of the latter is fixed a pin, which allows the mast to turn, carrying with it the jib, as in an ordinary crane, but with this great difference, that it can make a complete circle. The jib is fixed to the piston rod, P, by means of crossheads, which are at the same time made to carry the supporting wheels, running inside the channels of the mast, and bearing against the flanges. By this means the bending moment of the jib, and the weight thereon, are taken up, while the downward thrust is passed into the piston rod, P. When loaded, the cranes are capable of handling fully two tons with ease.

The H beams, formerly mentioned, are built up of tee and angle bars. These have first of all to be straightened, which is accomplished, in the case of the former, by means of a 15 in. hydraulic ram, and in that of the latter by an ordinary bending machine. All are then cut to the exact length of 32 ft. by a cold steel saw, moving with a velocity at the periphery of about 70 ft. per minute. They are now ready to be built into cast iron blocks on the drilling tables, and in building it is carefully attended to that there is a distance of 16 in. between the different joints of the angles, while those of the tees are placed midway between those of the angles. To secure good butting, the end of each new beam about to be built is placed hard against the one already set up, and to which it will be joined when placed in the tube; that is, the end of the new one is brought hard up against that of the old one, tee to tee, and angle to angle.

Everything being now in order, drilling, and that through angles and tees at one and the same time, proceeds, by means of radials of the style shown, Fig. 2. When this part is finished, the beams are marked and laid aside till they are required to be placed in a position on the mandrels, where, as is evident, the joints will meet as fitted in the shop. Thus this section proceeds, beam following beam till the total length required is completed. It may be mentioned that, as regards the arrangements of the tables, they are placed on each side of the line of radials, which allows building up to go on at the one side, while drilling is being proceeded with at the other. To insure accuracy in the form of the tubes, and also correctness in workmanship, the stiffening circular girders required are built within a wrought iron ring, the inside diameter of which is 12 ft., this being the mean size of the tubes at present under consideration. Within this ring, and at equal distances apart, are placed ten castings, each of which occupies the same relative position to the different parts of the girder as the longitudinal beams in the completed tube. These are also of a form suitable for carrying up the various parts of the girders while being drilled. When the girder has been built in this iron frame, all the holes are marked off to templet, and afterward drilled by a radial, the center of the column of which coincides with that of the girder. Although some of the girders vary slightly in diameter at some parts, according to whether they are off or on joint covers, this is easily overcome by fixing temporary packing strips against the ring to suit the new dimension to which they are of necessity built. After drilling, the separate parts are all marked, removed, and now bolted together, awaiting erection on the mandrel. The angle iron rings for these girders are curved on a large cast iron segmental block. A pin is fixed into the center of this segment, round which a large wrought iron arm carrying a curving wheel is moved. This wheel is of a form suitable to bear against the outside or inside of the bar as may be required. When the angle is heated, one of the ends is grabbed behind the wheel to the segment, and the arm is now gradually moved round. The wheel bearing hard against the angle, brings it close to the face of the segment, and it thus receives the proper curve. To assist the curving, a crow bar has to be used in front of the curving wheel to bend up the angle, while behind the wheel additional grabs keep it close to the segment. After the full bar has been curved in this manner, the grabs are removed and the wheel run backward and forward several times, and then it is ready to be removed, and with a little trimming up, fit to be used in any of the girders.

Having now considered the principal parts which compose the tubes, the building and drilling of these will naturally follow. This work is done out in the open, on what is called the drill roads. These are laid down to suit the drilling machines, and at such a distance and with such a length as to allow the bracing girders and connections thereto to be placed in position, as the work stands on the ground, prior to the final erection. The roads are so arranged as to be all equally suitable of access for the steam traveling cranes used in carrying the material to position and in building the tubes. This is accomplished by means of traversers, of which there are three, one in the center and one at each end of the drill roads, those at the ends running on rails, at right angles, and close to the main roads, but fully 12 in. lower, while the center one is run on cross rails, on the same level as the main roads. If it is necessary to change the position of a crane, it is run on to the traverser, and on it carried to the desired point, and there run off. In this way the whole of the ground is commanded by the cranes. It has already been said that the material for the tubes is placed in position by means of these cranes; the work of building, as required in any of them, will now be described.

Fig. 7 shows the style of building. First of all there is the mandrel, M, 45 ft. long by 5 ft. in diameter, raised on iron trestles, T, to a height, at the center, of 10 ft. from the ground. This corresponds with the center of the outer rings of the drilling machines. The great length of mandrel required is to allow of its being carried up at the ends, where the H beams and plates are built in position. On this mandrel there are now secured, but in halves, temporary iron rings, R, at the horizontal distance from each other of 8 ft. To these are fixed the radiating plates, P, having holes punched in the outer end for bolting on the first part of the permanent work, viz., the inner angle, A, of the circular stiffening girders. The same bolts are also made to carry the web plates, W, of these girders, on the outer edge of which is fixed the angle irons, I, for making the final connection to the shell of the tube. The horizontal H beams, H, are now placed in position, being securely bolted through the inner angle of the circular girders. On these beams are now placed the shell or tube plates, S, the ends forming butt joints, while longitudinally they lap one another, this taking place over the solid flange of the H beams. The end joint of the one plate breaks opposite the center, or solid part, of those on either side. The first plates to place in position are the inner, or those lying close against the flange of the beams, beginning generally at the bottom, and coming up on each side. Owing to the passing of the one plate beyond the other, one-half of each remains free to put grabs and drawwashers on, without interfering with the placing of the outer ones in position. So soon as the outer ones have been put on, and fixed in a similar manner, there is passed round all a couple of angle iron rings, for binding and drawing them up to their proper position. The tightening them up is done by means of iron wedges between the plates and the rings. After the bottom plates have been fixed in position, the tube is borne up by wooden blocks, built between it and the cradle underneath. The true position of the tubes, both as regards horizontal distance apart and height, is found by means of a theodolite, placed at one end of the roads, on a fixed platform, in a position such that when it is in line with a stationary point at the other end it always fixes the centers 120 ft. apart throughout, and horizontally in the same plane. If the center of the mandrel is not in this line, then it is made so by being raised, lowered, or shifted sideway to suit. When the mandrel is right, the tube must of necessity be so also, seeing the centers coincide.

When the building of one ring of plates has been completed, the drilling machine is moved forward, the blocks in front being taken out of the way and rebuilt behind as it is traveled along. To enable the drilling to go on continuously, the building of the tube in front is being proceeded with while the machine is still at work on the portion immediately behind. These tube drilling machines—of which there are four—are shown by Figs. 1 and 14. Each is self-contained, and on being run along the rails carries all with it. The principal parts are the wrought iron underframe or carriage, A, on the one side of which is fixed the engine, E, and boiler, B, and two large cast iron rings, C, firmly bolted to the main cross girders. These rings have an internal diameter of 13 ft., sufficient to enable them to pass freely round the tube when the machine is being moved along. Five cast iron slides, D, are fixed thereon, and held in position by means of small slipper blocks, F, fitting into a recess in each of the rings, C. On each of the slides are the two heads, HH. Each head is provided with a single drill, and is capable of being rapidly run from one point of the slide to another by rack and pinion gearing. The slides are kept in position, and also turned round the rings, C, in either direction, by means of two worms, W, carried in brackets, F, one gearing in each ring in the circular racks, R. These racks being bolted to the rings serve also as guides for steadying the whole upper portion of the machine. All the drills point to the center of the tube, and having, as shown, both a circular and longitudinal motion, can with ease be made to reach every hole in any part of the structure, some of which are through a depth of as much as 4 in. of solid metal.

It might be here mentioned that some of the slides were specially designed to overcome the difficulty of drilling, say, a flat part in any of the tubes. The difficulty lies in the fact that the drills on any of the fixed heads always point to the center of the tube, whereas in the case just mentioned the holes require to be drilled at right angles to the special or flat part. The mode adopted to overcome this was to make both ends of each slide circled, fitting them into separate heads, which in turn were bolted to the slipper blocks, F, as in the others. On the head at one end is placed a worm, while on the same end of the slide there is keyed a wheel into which the worm is geared, by turning which the slide can be made to place and keep the drill pointing in any required direction.

The whole of the drills are fed into their work by an automatic arrangement, the motion being imparted to the longitudinal shaft, L, by a band driven off the main driving pulley. On this shaft slides, and by it also are driven, the worms, W', necessary for turning the worm wheel, I, which at will can be made to drive the hand wheel, R, thereby feeding the drill into its work. At one end of each of the main slides is overhung the driving pulley, P, the power being transmitted from the engine to the whole of these by means of a cotton rope, guided where necessary by supplementary pulleys. The

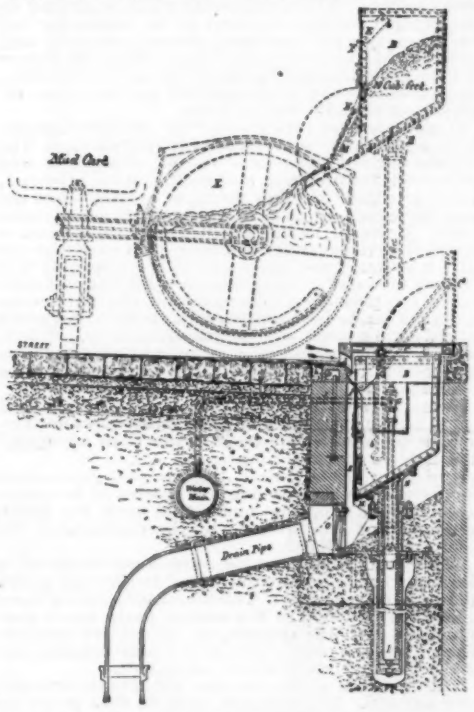
slack is taken up by a shifting quadrant, Q, moving about the engine shaft as a center, assisted by auxiliary pulleys on the wrought-iron frame close by the engine.

When starting work on any tube, a drilling machine is moved forward to the point at which operations are to begin. Each of the five slides is now moved around the rings until the points of the drills face truly any series of holes in the longitudinal beams. The holes in this line, or series, are all drilled, two drills being at work on each line, then the slides are again placed so as to suit a new set, and so on until the whole of the tube commanded by the machine in its present position is finished. This is equal in length to 8 ft., and includes the full circumference of the tube. The number of holes in such is about 800, and the time required to drill all, when working continuously, is from twenty-four to twenty-eight hours, varying thus much principally on account of the difference in thickness of the various parts of the tubes. The machine is in like manner made to drill the whole length of the tube.

At several of the ends of the first four of these tubes are presently being erected the skewbacks, each a complicated connection of five different tubes, including one end of these just described and also several heavy bracing girders. Into this, however, it is not proposed to enter at this time. At present other tubes are being treated in a manner similar to that already described, which shows, if anything is yet required, that special work can only be grappled with to advantage by the free use of special plant.

MUD AND GARBAGE RECEIVER.

WE illustrate below a new form of movable and self-emptying street mud-bin which has recently been introduced by W. B. Powell, London, and described in *Engineering*. The arrangement is very simple, and consists of an iron or steel receptacle which is attached directly to a hydraulic ram, as shown. The ram is worked by the pressure in the water company's main,



MUD AND GARBAGE RECEIVER AND LIFT.

and lifts the receiver sufficiently high to command the scavenger's cart. A door is then opened at the side, and the contents fall by gravity into the cart, sliding along the sloping bottom of the cage; or if required the latter can be tilted on trunnions. The waste water from the hydraulic cylinder is used for flushing the pit in which the receiver is placed. The way in which the ram is guided in the case is very simple. A V-shaped guide is cast on to the interior of the case, and this fits a corresponding notch in the ram, the latter being swelled at the end nearly as large as the case, and so proves at the same time a stop by coming in contact with the top box.

Our present method of removing street refuse or domestic garbage is offensive and uncleanly, so that any practical improvement by which the operation could be performed should receive every attention.

IMPROVED COMPOUND ENGINES.

THESE engines are used in connection with the electric lighting machines of the London Stock Exchange. They were made by Messrs. Willans and Robinson, of Thames Ditton, and are of the latest type of the Willans special compound engine for electric lighting, which differs in many respects from Mr. Willans' still better known marine engines. They are designed to indicate 60 horse-power each, at 600 revolutions per minute, and at this high speed they work with great silence and steadiness. To be seen to the best advantage they ought to be coupled directly to the dynamos, but owing to the great working speed of the latter this is impracticable, and they are driven by belts in what may be called the old-fashioned way. The high speed of the engines has, however, the advantage of rendering counter-shafting unnecessary, and to this extent space is saved, over and above the saving due to the small dimensions of the engines themselves, the base of each engine measuring only 3 ft. 2 in. by 2 ft. The high-pressure cylinders are of 4½ in. diameter, and the low-pressure 9 in., the stroke being 6 in.

Each of the pistons driving the three cranks, A, B, C, consists of three parts, viz., (1) the low-pressure piston; (2) the high-pressure piston; (3) the cut-off rod or trunk, forming the valve for one of the high-pressure cylinders; *a*, *b*, *c* are the crossheads, taking the form of deep trunk pistons without rings, moving in guide cylinders. The latter are open to the crank chamber at the bottom, and are lubricated by the splash from the cranks. D, E, F are the connecting rods, of ample length; G, the crank shaft, running in phosphor-bronze bearings. The cranks and connecting rods work in the "crank chamber," K, containing oil, which is continually splashed up in spray over all the bearings, and up the inside of the hollow crosshead pistons to the steel pins upon which the upper ends of the connecting rods work. As there is constant down thrust upon all working parts, there is not much occasion for brasses *below* the crank pins, but to guard against accident, brasses are fitted, but of reduced length. As they rarely, if ever, come into action, the setting up of the brasses is a matter which at most needs attention at very long intervals.

The three cranks being set at equal angles of 120 deg., the piston, B^2, has just the proper lead of A^1 to enable it to supply A^1 with steam, with cut off at three-quarter stroke, and admission at the commencement of the stroke. This describes not only the relation of B^2 to A^1, but of A^2 to C^1, and of C^3 to B^1. Exactly similar relations exist between the cut-off rods B^3, A^3, C^3, and A^2, C^2, and B^2, respectively.

The cut-off rod, B^3, which supplies steam to A^2, commences to uncover the ports leading to A^2 when the latter is at the top of its stroke. B^3 (on its way up) closes these ports again when A^2 is at three-quarter stroke. At about the same time, A^2 begins to uncover the ports in the side of its own cylinder, which allow the steam, still acting upon A^2, to act also upon C^1, then at the top of its stroke. From this point until A^2 reaches the bottom of its stroke, the steam expands on A^2 and C^1 together. A^2 then commences to rise, against a pressure which rapidly diminishes as C^1 continues its down stroke. When C^1 has traveled three-quarters of its stroke, A^2, rising, has covered up the port. Thenceforth the steam shut in above A^2 has no exit, and the clearances are so proportioned (including the high-pressure passages) that it is compressed approximately to the initial pressure.

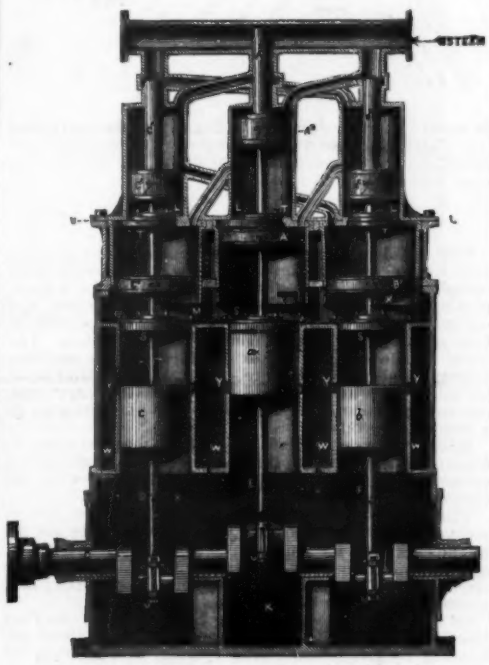


FIG. 1.—COMPOUND STEAM ENGINES.

To return to the steam above C^1. Communication with A^2 being severed, this continues to expand until, just before the end of the stroke, C^1 commences to uncover the oblong ports shown in the figure. By these openings a great part of the steam in the cylinder, and, what is of great importance, *all the water*, are ejected into the space, X, which communicates with the exhaust. It will be noticed that the position of the exhaust ports is much nearer to the lowest position of the piston in the low-pressure than it is in the high-pressure cylinders, and that the ports are consequently uncovered for a much shorter time. The reason of course is that, in the one case, the removal of the steam and water has alone to be considered, while in the other the time of opening has to be adjusted to suit the desired period of admission for the low-pressure cylinder. By the time C^2 has again closed the ports of its own automatic exhaust, the upward movement of A^2 has placed the steam still remaining above C^1 in communication with the space, L, through which it can pass away to the exhaust (by an opening not shown) during nearly the whole of the upstroke.

The rods by which the high-pressure parts of the pistons are attached to the low-pressure parts pass through metallic glands, T, which consist only of spring rings like piston rings, and require no packing. Similar glands, S, separate the exhaust space, X, from the guide cylinders and the crank chamber.

Mention has been made of compression in the high-pressure cylinders, where—chiefly owing to the considerable fraction of the stroke during which it takes place, and the character of the curve of compression in relation to that of expansion—it involves extremely little loss. Little or no compression is given in the low-pressure cylinders, and in the Willans engines of the marine type the compression in the high-pressure cylinders is alone amply sufficient to give the required "holding-down power," and to keep the connecting rod brasses always in thrust against the crank pins, and the crank shaft always against the lower side of the main bearings. But at the very high speeds required in electric lighting work, other provision has to be made; and the special means adopted to absorb the momentum of the moving parts during the upstroke are among the most characteristic features of the Willans engine. Besides its wastefulness when carried to excess, compression of steam in the cylinders is open to the objection that under varying conditions of working varying effects are produced. To avoid these, recourse has been had to a different fluid, which is always available and of which the character and pressure are invariable. Upon the upstroke of each piston, work is put into the compression of *air*—to be given out again without appreciable loss upon the succeeding downstroke. The means by which this is effected, without adding any parts to the engine, is the subject of a separate patent. The cylinders in which the piston guides, *a*, *b*, *c*, work are closed at the upper end. At Y, Y, Y, are holes opening into the chamber, W, the latter being in communication with the atmosphere, and by drain holes at the bottom with the crank chamber, K. Toward the end of the down stroke the guide pistons uncover the holes, to insure that the air-pressure in the cylinders shall be restored once in each revolution to that of the atmosphere. On the upstroke, as soon as the holes are covered, compression commences, and is carried to an extent governed by the amount of clearance provided

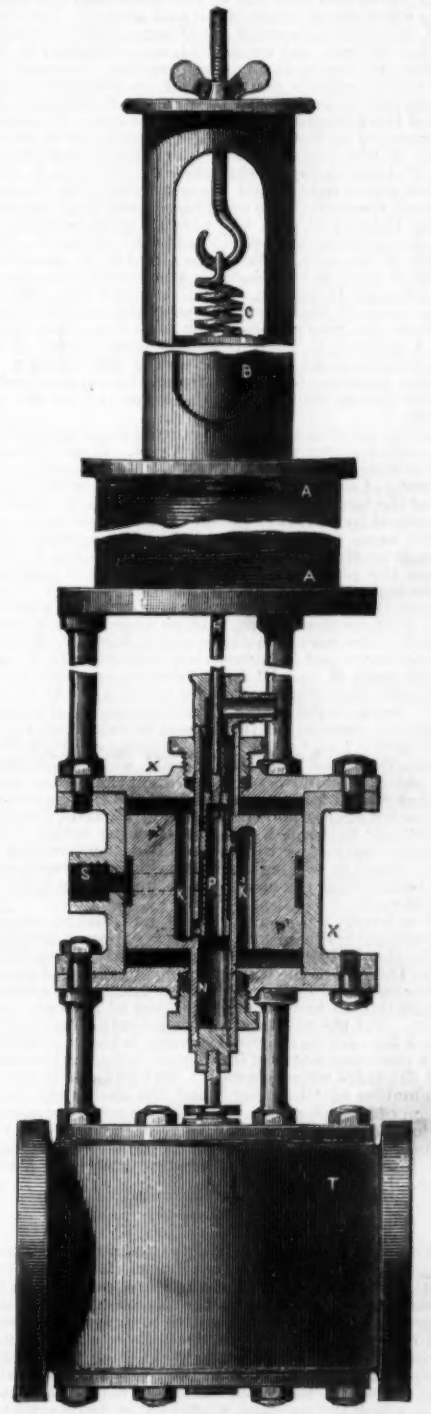


FIG. 2.—THE ELECTRICAL GOVERNOR.

(which can be varied within certain limits). On the next downstroke the air assists in driving the engine. Even if by the action of the governor, or by other means, the steam is wholly shut off while the engine continues to run, the effect of the "air-buffers" is not impaired; they are wholly independent of steam pressure, and the valve action of the engine may be designed without the smallest reference to questions of compression other than that in the high-pressure cylinders already referred to. It need not be said how great an advantage this is, or how largely it contributes to the remarkable economy achieved by these engines.

The most striking feature of the installation, from an electrical point of view, is the use of the Willans electrical governor, for regulating the speed of the engines, so that by varying the speed the electromotive force may be kept constant. How great progress is being made by Mr. Willans' invention is shown by the fact that already upward of forty of these governors have been either applied or are about to be applied in installations. Even in the case of compound-wound machines it is becoming apparent that an electrical governor, which will keep the speed at least as uniform

as the best centrifugal governor so long as uniformity is to be desired, and varies it if variation should be necessary, is preferable to a governor which can at best perform but one of these functions. But the electrical governor is seen to the best advantage when applied to shunt machines, which not only can scarcely be used without it (where great variations have to be dealt with), but which become, when used with it, as perfect as the more expensive compound machines. By arranging to work with the electrical governor, therefore, Messrs. Woodhouse and Rawson have been enabled to use shunt-wound machines.

THE ELECTRICAL GOVERNOR.

In Fig. 2, which represents one of the Willans electrical governors in question, A A are the coils of a solenoid which form a shunt between the terminals of the machine, and B is an iron core suspended inside the solenoid by a spring, so adjusted that when a current due to the normal electromotive force is passing through the coils, the core shall occupy a position in which a small movement one way or the other shall not materially affect the strength of the pull upon it. The solenoid, it will be understood, is pulling against the spring, so that if from any cause, such as a reduction in the number of lamps, the current becomes stronger, the core will be drawn downward; if, on the other hand, the current is weakened, the spring will overcome the pull of the solenoid, and will raise the core. The latter is connected by the rod, R, with a small double piston valve, P, which works inside the main hydraulic piston, P^1, as the latter works inside the cylinder, X. The hollow piston rods, N and N^1—connected with P^1—pass through the ends of the cylinder, X, and N^1 is connected by the rod, F, with the throttle valve, which is of the piston form, and works inside the casing, T. The piston, P^1, has an annular space round it, M, into which water or other fluid pressure is admitted by the pipe, S. By a passage therefrom, shown in dotted lines, the annular space, M, communicates with the annular space between the two pistons which form the piston valve, P. A passage, K, leads from the lower piston of the piston valve, P, to the upper end of the cylinder. A similar passage, K^1, leads from the upper piston of the piston valve, P, to the lower end of the cylinder.

In the position shown, the current is supposed to be constant and the machine is at rest. If now the current is increased, the piston valve, P, is lowered by the lowering of the core, B, and pressure is admitted to the top of the large piston, P', by the passage, K, which is uncovered by the lower piston of the piston valve, and at the same time the space below P' is opened to the exhaust by the passage, K', and the hollow rod, N. This causes the piston, P', to descend, and as it descends it closes the throttle valve by means of the rod, F, and reduces the speed of the engine and dynamo, which in turn weakens the current, and so stops the downward motion of the core, B, and the piston valve, P. The latter coming to rest is immediately overtaken by P', and the passages, K and K', being brought opposite to the now stationary piston valve, are closed, and the motion of P', owing to the inelastic fluid employed, is also immediately arrested. If the current is weakened, the reverse action takes place. The sequence of the various actions described is extremely rapid, and consequently the piston, P', follows so closely upon the piston valve, P, that the stopping or slowing of the latter produces an instant effect upon the motion of P', and "hunting" is entirely prevented. This overtaking action is in a measure analogous to the so-called "differential action" found in various steam steering gears, but it need not be said that the manner of its application is entirely different.

It is hardly necessary to point out that no solenoid of practicable dimensions could exert power enough to move the throttle valve direct, and that the system of using the pull of the core to bring another and greater power into action—in other words, the use of a relay—is essential to the efficient working of such an apparatus. But the substance of the invention, and that to which its owes its practical success, is the combination with the relay motor of interaction between the motor and the valve which starts it. To this alone is due the elimination of "hunting" and the absolutely steady action of the apparatus. The Willans governor assumes various forms to meet different requirements, but that which we have illustrated may be considered the standard form for actuating a throttle valve.—*The Electrician.*

A LONDON SUBWAY.

AT a recent meeting of the City Commission of Sewers, London, Mr. H. H. Bridgman moved that on the completion of the purchase of the European Tavern and other properties opposite the Mansion House, it be referred to the Streets committee to consider and report as to the necessity and practicability of constructing a subway across the street, to avoid the present danger of crossing and to facilitate the traffic in that locality. The scheme, of which he submitted a plan and map—from which the annexed engraving is taken—contemplated the erection in the center of the roadway between the Mansion House and the Bank of a circular chamber about 20 ft. in diameter, with an 8 ft. skylight at the top. Around this he would place, on the surface, a pavement 6 ft. wide, which would be an effective refuge for foot passengers who preferred to cross above ground. Under the surface the plan was to construct four radiating subways from the center to the Union Bank at the corner of Prince's street, to the northeast corner of the Mansion House, to the open space in front of the Royal Exchange, and to the Liverpool and London and Globe Insurance office at the corner of Lombard street and Cornhill. Several objections had been and might be raised to the proposal, but none, he thought, were insuperable. As far as the gas and water pipes and the sewers were concerned, the difficulty could be overcome, as it had been in other improvements. It had been surmised that the owners of property at the spot would offer objections, but the result of interviews he had had with them did not lead him to imagine that the objections, if any, would be serious. The Lord Mayor saw no difficulty in access being obtained to the subway from a part of the basement of the Mansion House, and had spoken of the need of such an improvement. The Royal Exchange site presented no difficulty, for it was in the hands of the Commission, and an underground improvement now being constructed there would facilitate matters. The subways would be lined with glazed white bricks from end to end, the central chamber and the staircases would be lighted with the electric light, and the subways would be watched and guarded during the day and closed at night. It had been urged that bridges across the thoroughfares would be more useful than underground ways, but he contended that they would create more obstruction and occasion more danger than they would obviate. As to the necessity for such an improvement, let them consider the enormous pedestrian and vehicular traffic passing the spot daily. The traffic had now increased 29 or 30 per cent. since 1860, and it was computed that 70,000 persons now crossed the street in nine hours of the day, and 1.8,000 in the twenty-four hours, or at the rate of over 34,000,000 a year. These people had now either to thread their way among horses and vehicles at great danger to life and limb, or the vehicular traffic had to stop every few minutes to allow them to pass.

In regard to the vehicular traffic, it was stated that at that particular spot vehicles passed in sixteen different directions at the rate of 54,000 a day, or 17,000,000 a year; and it was still increasing.

ON THE HEATING OF CARS.

THE problem of heating of cars of all classes appears very simple at first sight, yet is nevertheless a most complex one, and one difficult of solution. In a question of this nature the least details are important, and we may even say, *a priori*, that it is nearly impossible to find a system that can be universally adopted. The form of the car, the tastes of the travelers, and the exigencies of the service are so many factors that must be taken into account, and that evidently vary from one country to another, and even from one company to a neighboring one.

However, in order that our readers may be able to form a rational opinion for themselves, we shall pass in review the principal systems proposed, along with the results that each of them has given.

The number of solutions applied in France is now reduced to seven. They are as follows: stoves set up in the cars; hot air apparatus; apparatus for burning agglomerated fuel; steam heating; heating by gas; circulation of hot water in stationary apparatus; and movable hot water heaters.

Of all these modes of heating there are only two that the Company of the East has not tried, and these are heating by gas (Chaumont's system) and heating by steam.

The Chaumont apparatus, which has been experimented with by the State Company of Belgium, gives a satisfactory calorific performance, but is costly and complicated, and the expense due to its consumption of fuel is considerable. However, the questions of heating and lighting by gas are interdependent, and, in order to pronounce upon the former, it is necessary to wait until the latter has become truly practical.

As for heating by steam, that requires a continuous communication between the cars of the same train, either whether the generator is upon the locomotive or in a special car. Now such communication, which is greatly in the way of the maneuvering, presents the inconvenience of preventing the heating of the train, wholly or in part, when one of the coupling pipes happens to burst. And such an accident may occur more frequently than would be supposed, through the congelation of condensed water in the system when the valves work badly. Moreover, the system costs much to install, and, as all parts of it are very delicate, the cost of keeping it in repair is considerable. Let us mention, in passing, the risk of fire and explosion in the case of a special generator, and let us add in conclusion that all French travelers who have ridden in cars heated by steam have experienced a general feeling of insecurity.

All the other systems have been studied with the greatest care and under the best conditions possible, and in always applying the improvements that experience had indicated.

Heating by Stoves.—Nothing appears simpler than to heat a given space by means of a stove; so the solution of the problem under consideration seems to be clearly pointed out. But with French rolling stock we cannot seriously think of putting a stove into each compartment, and the system is therefore scarcely applicable to the single cars of the third class. The model that has been tried is the coke stove, type D, No. 5, of the Paris Gas Company. Each apparatus, all set up, costs fifty dollars, and its daily consumption of fuel costs one cent per hour of running and half a cent per hour of stoppage. As may be seen, this plan has the advantage of being economical, but it has also the following drawbacks: The air in the car, in obedience to the law of densities, increases from the floor to the roof, and the travelers therefore have warmer heads than feet—an unhealthy and dangerous condition. The vicinity of the stove cannot be occupied without grave inconvenience, because of the high temperature that occurs there. Finally, the distant regions are but slightly or not at all heated. It is necessary to add, also, that since each car carries with it a fireplace full of incandescent coal, danger from fire is to be apprehended in case of a collision.

The reception given by the public to this mode of heating rendered the experiment decisive. The heated cars were generally deserted, and the few passengers who took seats in them threw the doors wide open in order to overcome the heat that discommoded them.

Hot Air Apparatus.—The first apparatus tried was that of Messrs. Grandvallet & Kienast. We shall say but a few words about it, since the results obtained were negative. The cost of putting it in amounted to one hundred and sixty dollars, and the expense for fuel was three cents per hour with nitrated charcoal, and one and a half cents with new coal. With the former fuel the mean temperature of the car rose to but 4 deg. above that of out of doors, and with the latter the effective performance was but 3 deg.

Trials were afterward made of the Mousseron apparatus, a hot air stove placed externally to each car. The running of the latter caused the introduction of cold air around the fireplace, and this, after being heated, passed into the car. This system of heating offers the same inconvenience as do stoves for distributing strata of air. Moreover, as the calorific capacity of the air is very feeble, the quantity of heat stored up in each car cannot be much, and disappears at every opening of a window or door. Hence, alternate heating and chilling of the passengers. In addition, the latter complained of headaches resulting from the bad odor of the heated air in contact with the cast-iron stoves. In fact, at a high temperature, the metallic side is permeable to gases due to combustion, which diffuse themselves externally.

As may be seen, it is bad in principle and prejudicial to the public health to send hot air into cars, and travelers prefer to suffer from cold rather than be obliged to endure an apoplectic heat.

Apparatus for Burning Agglomerated Fuel.—Two apparatus have been tried in this process of heating—that of Grandjean, now under trial upon the Dutch railroads, and one invented by the engineers of the Company of the East.

The Grandjean apparatus consists essentially of a sheet iron heater set into the floor of the car and placed under the travelers' feet. This heater is formed of three concentric jackets. In the central part, which communicates with the exterior, are placed the braziers. The entire system is covered with a plate forming part of the floor and provided with an air-hole.

This system is costly, and the effective performance very unequal. The charging must be done in the interior of the car, and the introduction of braziers, full of incandescent coal, into the cars, is a cause of waste, and of danger from fire. Besides, since the joints cannot be perfectly tight, there has been found in air taken from the surface of the flow, two hours after firing up, a proportion of $\frac{1}{10}$ per cent. of carbonic acid.

Circulation of Hot Water in Stationary Apparatus (Thermosiphons).—Two slightly different models of the Weibel and Briquet apparatus were first tried. This consists essentially of a boiler placed under the box of each car, and in which water is heated through contact with a central fireplace. This water is afterward distributed through the heating pipes by means of a system of piping fixed in the interior of the car. It is, in short, a thermosiphon analogous to those that serve to heat dwellings and greenhouse.

This system, the results of which were pretty good, showed that the practical solution of the question lay in the use of hot water. But the arrangement adopted presented great inconveniences. Thus, the temperature was higher near the upper part of the car than near the floor, and it was not possible for the traveler to keep his feet warm; and, finally, the piping in the

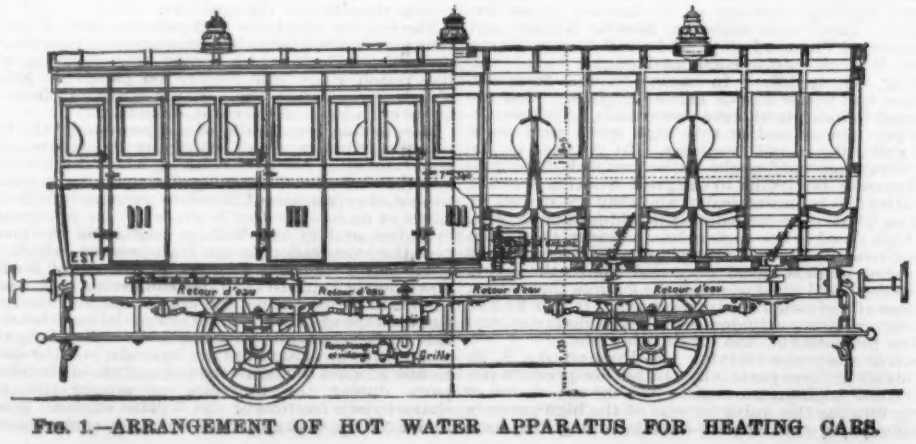


FIG. 1.—ARRANGEMENT OF HOT WATER APPARATUS FOR HEATING CARS.

interior of the cars rendered it difficult to keep the apparatus in order, and made damage possible in case a joint should leak.

All these drawbacks, with a few other details, that we shall pass over, decided the engineers of the company to devise another apparatus founded upon the same principle. This is shown in Fig. 1.

In this new arrangement the boiler was suspended beneath the car, and metallic boxes set into the floor of the car served as heaters. A distributing pipe that started from the top of the boiler connected the extremities of the heaters on one side of the car, and a return pipe connected the other extremities of the heaters and ended at the lower part of the boiler. The following are the results that were obtained in a third-class car: The internal temperature was, on an average, 9°88° above that of the external air. The distribution of the heat was good, and the latter was greater on the floor than near the roof. The variations in temperature at different points of the car were from 4° to 5°. The thermometer in contact with the heaters marked 50°, which was sufficient. The opening of the doors was found to have but little influence on the temperature.

This apparatus, which is capable of improvement, is good in principle. The objection that may be made to it is the slowness with which it effects the first heating, the presence of a fireplace in each carriage, and especially the possible congelation of water in case the fire is extinguished. But such drawbacks are not without their remedy, and are not sufficient to cause the system to be rejected.

Movable Hot Water Heaters.—The heaters employed in this plan are so well known that it is useless to describe them.

Each heater delivered to the passengers costs the company, all expenses included, about two and eight-tenths cents, and lasts for about two hours. There is no expense of arranging the cars, since the apparatus are entirely independent of the rolling stock; and, what is much appreciated by the passengers, it is possible for them with this system to keep their feet warm.

It is proper to offset these advantages with the following inconveniences. The slight degree of heat does not warm the compartment. The quite rapid cooling of the heaters requires a frequent renewal, which, during night especially, causes the travelers great annoyance

As regards maneuvering, it takes quite a number of men to handle the heaters with dispatch, and the operations of emptying and filling take much time, and soon injure the apparatus.

There are two improvements that can easily be introduced, and that is the use of very hot water, and the doing away with filling and emptying. These can be effected at one and the same time, either by injecting superheated steam into the heaters, or by a pure and simple immersion of the heaters in a bath of very hot water.

The former process is employed by the Orleans Company. It is a rapid one, and permits of the heaters being prepared in advance; but the objection can be made to it that it requires a considerable number of heavy and costly carts, causes a loss of time through the operations of closing and opening at the period of each injection, and quite quickly injures the closing mechanism.

The second process is used by the Company of the East. In order to render the manipulations easy and rapid, Mr. Regray has devised an apparatus which we represent in Fig. 2. Two endless chains run into a well filled with hot water, and form a sort of noria. The heaters are placed in the successive links, and the latter, being carried along by the sufficiently slow motion of a drum, are led in turn to a proper height to receive, on the one hand, the cold heater, and, on the other, to permit the hot one to be removed. Directing curves are so arranged as to render these two operations after a manner automatic. Upon the heaters making their exit, two crossed brushes remove the water that adheres to them.

The temperature is kept up to 100 deg. in the well through an injection of steam derived from a special boiler. This latter is fed by a small portable engine, which also actuates the drum. Each heater remains immersed for fire minutes, and each apparatus furnishes 288 heaters per hour. The interval between each immersion is twelve and a half seconds, a sufficient length of time for the maneuvering.

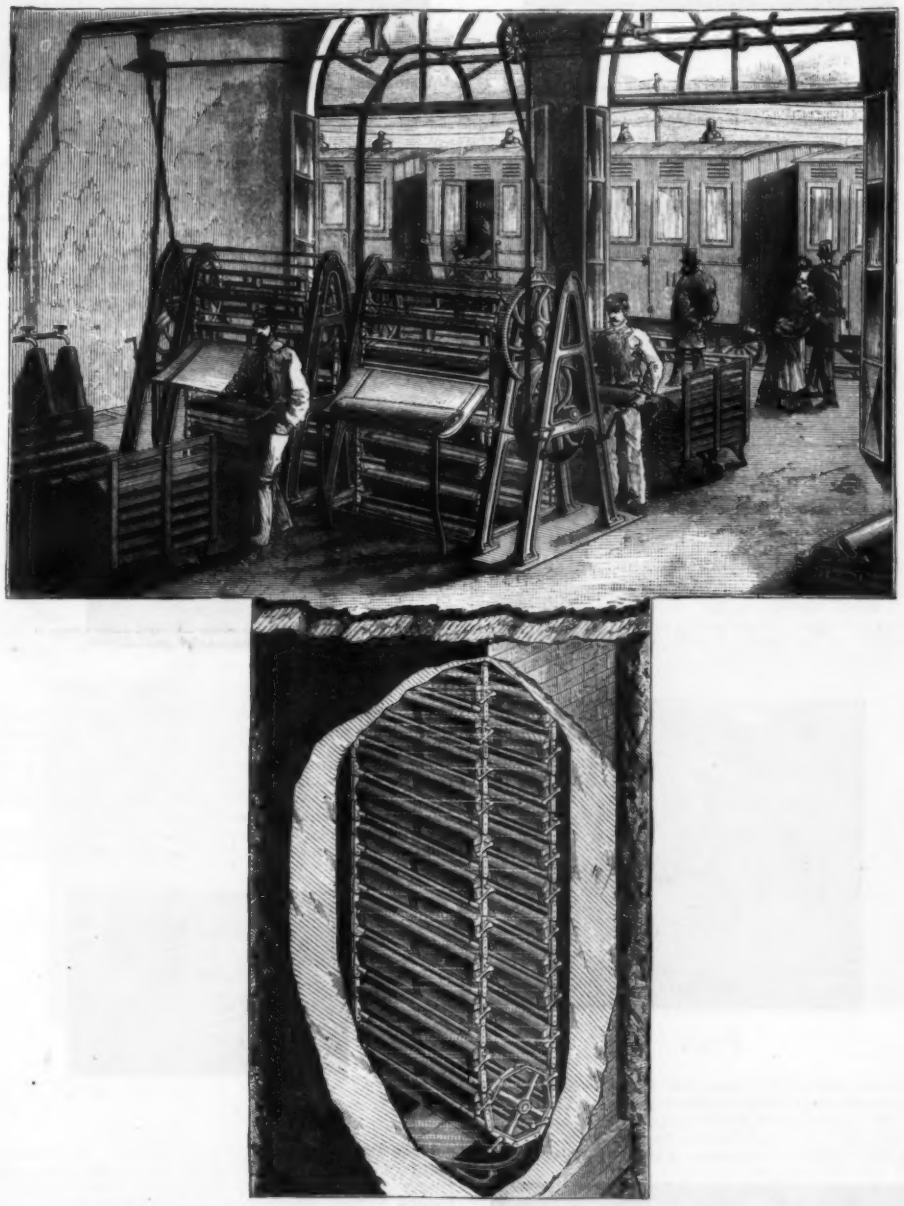


FIG. 2.—REGRAY'S APPARATUS FOR HEATING CAR WARMERS.

It is demonstrated, then, that the question of the rapid heating of the apparatus is now solved, and that it is henceforth possible to heat cars of all classes by this system, which, although not perfect, sufficiently satisfies the conditions to be fulfilled.

The reader has now before him the details of the process. He will recognize, as we do, that the problem is not as simple as it seems, since, in spite of long and patient efforts, and of ingenious and varied arrangements, the final solution has not as yet been found.

Nevertheless, from the discussion of the different systems, one thing is clearly and definitely shown, and that is that hot water is the calorific medium that will give a solution of the problem. Such a result might have been foreseen from a comparison of the specific heats of different bodies.

While the experiments were in progress, the public took a decided stand against the processes that are well received in foreign countries. There is nothing surprising in this, since the cold is more intense in Germany, Austria, and Russia than in the less favored parts of our own land.

Everything considered, France has done well this time by waiting. She has thus been enabled to profit by the experience acquired by her neighbors; and, as Mr. Regray says, "She will only have to congratulate herself for having stopped at a solution that time has ripened and study has consecrated."—*La Nature.*

FRUIT CANNING IN LONDON.

THE past season has been in many respects an exceptionally good one for the manufacture of fruit preserves. This industry is increasing yearly in importance, and seems likely, before long, as in the case of many other industries, to fall almost entirely into the hands of the larger houses, who have the command of sufficient capital to bring the resources of machinery to bear upon the different processes employed.

During the height of the preserving season we had an opportunity of visiting the London factory of Messrs. J. Moir and Sons, where fruit of all descriptions is preserved on a large scale. The raw material, consisting of baskets of strawberries, currants, gooseberries, etc., is gathered in the market gardens which surround the metropolis, at the earliest hours in the morning, it being a point with this firm that all fruit should be converted into jam before the evening of the day on which it is plucked. In the boiling room there are long rows of jacketed copper pans, each of about 60 gallons capacity. Steam at a pressure of about 50 lb. to the square inch is admitted into the jacket, and the fruit is poured into the pan. Each pan is served from above by a trough through which the loaf sugar, having been previously crushed in a mill and weighed by an automatic apparatus, is shot on to the fruit, and the whole is boiled for a sufficient time. Some of the pans are made to swing on trunnions, the steam passing through the latter as in an oscillating engine, while others are provided with an ingenious valve arrangement for emptying, in which case the necessary operations can be performed without tilting at all. The latter arrangement is found a great convenience in practical work, as it takes less time and occupies less space. In order to preserve the flavor of the fruit, it is necessary that no water should be used in cleansing it, and consequently many ingenious devices have to be introduced for the purpose. In the case of red currants, for instance, which seem somehow to possess a special power for attracting "matter out of place," a cylindrical sieve containing revolving brushes of a peculiar description is used. This runs at a speed of 1,200 revolutions per minute. The fruit passes through the sieve, while the stalks and other refuse are discharged at the lower end perfectly dry.

For making fruit jellies the fruit is boiled, and the first of the juice separated by means of open straining bags. The fruit is then placed in a centrifugal separator, consisting of an open-work basket rotated by a vertical shaft. This runs at a great speed, and almost instantaneously separates the fluid parts of the fruit from the skins and seeds. There is also a somewhat extensive hydraulic plant, consisting of pumping engines and presses, which is used with some fruits in place of the centrifugal machine for making jellies. As these jellies are slightly acid, earthenware vessels, pipes, and taps are used in their preparation.

It is said by those interested in this trade, that through the excessive competition of the present day in the jam-making industry, firms that manufacture a good article from sound fruit can only manage to exist by means of the closest attention to economy in production. However this may be, Messrs. Moir and Sons appear to have brought their labor-saving appliances to a high degree of perfection, and this most noticeably in the "filling room." The material is here carried in copper pans with wheels running on a tramway, and passes by gravity on to a hydraulic lift which raises it to an overhead gantry. Beneath the latter is a range of filling vessels, and the pan, which is fitted with a valve at the bottom, stops over each vessel and delivers the exact quantity of material required. Beneath the filling vessels the jampots (which have been previously washed in a steam-driven machine) are brought up by an automatic arrangement, each pot stopping in turn until it receives its full complement of preserve, when it passes on to make room for the next. In this way thirty to forty thousand pots of jam are filled in an ordinary day's work, the attention of one man or boy to each set of apparatus being alone required. It is the fashion now to pack a good deal of the best quality of jam in glass bottles, and these are filled in the same way. No machinery has, we believe, yet been devised by which the ordinary cover can be stretched and tied over a jampot, but the bottles have long been closed by an automatic arrangement. The stopper consists of a stout tin capsule, inside which is a thin disk of cork provided for the purpose of preventing contact between the fruit and the metal. The cork and the capsule having been put in position, the bottle is held firmly in a revolving holder by means of a weight. A pair of rollers are brought up to the capsule, and close it under the projecting flange on the neck of the bottle. Each machine will turn out about 300 bottles per hour in ordinary work. The quickness and precision with which the jampots and bottles are automatically taken from the stacks and marshaled into rows, and are then brought up to be filled by the various machines, is not a little comical at first sight. In another department of this factory pickles are made by the ordinary process, or rather what should be the ordinary process, only distilled vinegar being used in place of the coarser acids which are employed by less scrupulous manufacturers.

Cooked whitebait packed in tins and fried soles preserved by the same means are special features at Messrs. Moir's London branch, the soups for which they are well known being made at the Aberdeen establishment. The whitebait are fried in open-work wire baskets in marrow.

There is a building set apart for making the tins used on the premises. Here there are power presses and stamps driven by a separate engine. We understand that over 2,000 packages an hour are sometimes turned out from this department. Steam machinery is also used for stamping the circular pieces of paper which are used for covering the jampots.

Although the machinery here in use for making tin packages is comparatively new, it will shortly be superseded by an entirely fresh plant of novel design by which the labor will be still further reduced. The machines have been especially designed for the firm, and

we hope to be able to publish particulars of them at a future time.

This firm has other factories at Aberdeen, Wilmington, Delaware, and Seville. At the latter establishment orange marmalade alone is made.

The works of Messrs. Moir and Sons are instructive if only for the purpose of showing how largely machinery is now used in every branch of industry, even in one so apparently simple as making jam.—*Engineering.*

ELECTRO-CHEMICAL RINGS COMPARED WITH THOSE OBTAINED BY PHYSICAL, MECHANICAL, OR CHEMICAL WAY.*

II.

FIG. 1, obtained through diffraction, when light was passing through two contiguous and very small aper-

FIG. 1.

tures in a dark room, has much analogy in form with the hydrodynamic, Fig. 2, obtained through the fall of a small stream of water upon a pane of glass covered with a layer of red lead. In the same way we obtain through diffraction, and with three, four, or more apertures, ternary, quaternary, etc., figures (Figs. 3 and 4) analogous to the hydrodynamic rings of corresponding systems and to the magnetic phantoms of three, four, etc., electric currents or magnets.

FIG. 2.

The analogy between electro-chemical, hydrodynamic, optical, and acoustic figures is also kept up upon square plates, as shown in Fig. 5, c, c', d, d', to which might be joined the corresponding thermic and chemical figures.

Figs. 6 and 7, as well as 8, a, a', b, b', show the resemblance of optical and acoustical effects.

We may point out still another approximation between the elliptic rings produced (a) by electro-chemical or elec-

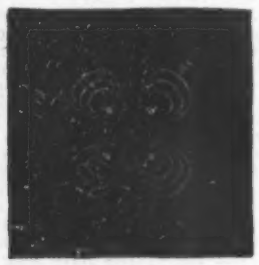


FIG. 3.

trostatic way, when the point is oblique to the projection plate (Fig. 9, a and a'); (b) by thermic or chemical way, when the plate is oblique to the flame or vapor (Fig. 9, b and c); (c) by hydrodynamic way, when the fall of a drop or stream of water, or of a liquid or gaseous current, is oblique to the glass plate (Fig. 10); and (d) by optical way, in crystals of two axes (Brewster's rings). These rings, which are alternately brilliant and black in the simple light, become iridescent in white

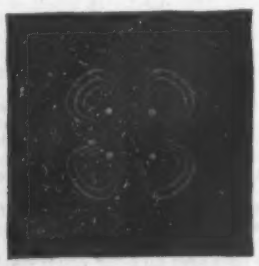


FIG. 4.

light (polarized). Fig. 11 represents the particular case in which the plane of the axes is parallel with the primitive plane of polarization.

* Continued from SUPPLEMENT No. 477, page 7614.

It will be seen that these elliptical figures, which are obtained under what may be termed corresponding conditions, possess evident analogies with each other.

Finally, in optical experiments we find examples of reflected rings, some with a white and others with a

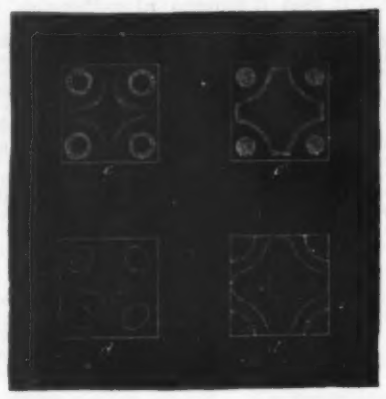


FIG. 5.

black center, in which the brilliant zones of the one correspond to the dark ones of the other (Fig. 12).

Analogous results are represented in our direct and inverse hydrodynamic rings, corresponding to the effects of polarity of electro-chemical ones.

FIG. 6.

Gaseous Rings.—When, by means of a tube about ¼ of an inch in diameter, we blow smoke gently against a wet pane of glass, we produce very fugitive rings. If we operate with a closed vessel, the rings will be fixed, the current itself being uniform. But the experiment

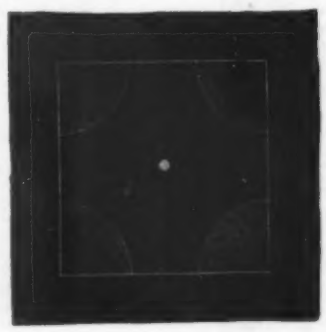


FIG. 7.

that most perfectly shows the phenomenon is that which consists in rendering the current of smoke automatic by means of a suction apparatus—an arrangement analogous to that devised by Mr. Nickles for analyzing the flame of a candle. A tube of glass tapering

FIG. 8.

to a point, or, better still, a blow-pipe, traverses a cork that hermetically closes a large jar which is provided beneath with a faucet and is half full of water (Fig. 13). The point of the tube entering the flame up to its center, and the cock being gradually opened, a continuous column of white smoke descends vertically to the surface of the water (as a continuous vein of liquid would do), where it forms several concentric rings (Fig. 14), whose relief soon increases with the thickness of the heavy stratum of smoke. The candle and tube may be

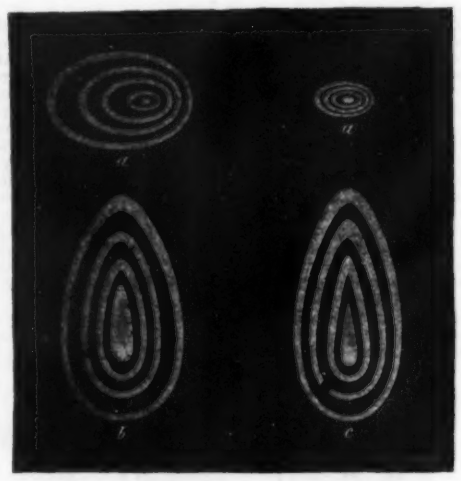


FIG. 9.

replaced by a cigarette inserted into a straight tube of suitable diameter. In this way may be avoided the deposit of fatty matter, which soon obstructs the tube, if it be a fine one, and puts an end to the experiment.

By these means we may produce multiple rings of smoke, by fitting to the cork the stems of several pipes, or straight tubes containing cigarettes, as shown in Fig. 16. The systems of binary, ternary, etc., rings that form under such circumstances are analogous to

FIG. 10.

the corresponding multiple liquid rings that have already been described; that is to say, the gaseous waves of each group of simultaneous rings repel each other without mingling or becoming superposed—in a word, they do not interfere, and thus they form systems that are perfectly distinct, but much wider and especially much thicker than hydrodynamic ones (Fig. 17).

Unfortunately, the number of rings quickly diminishes in measure as the stratum of smoke resting upon the

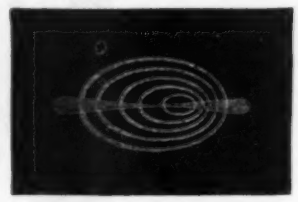


FIG. 11.

surface of the water becomes thicker. In the experiments with simple rings we end in having but a single ring with a very thick rim (Fig. 15). This effect is analogous to that which is produced by the fall of a continuous stream of water on the surface of a liquid thicker than half an inch. We know of various circumstances under which rings of smoke or vapor are produced. For example, in the spontaneous combustion of phosphureted hydrogen, the vapors of phosphoric acid that result therefrom rise and roll up in horizontal

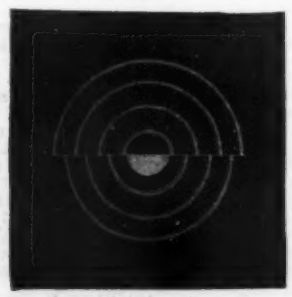


FIG. 12.

white rings in still air. These rings, whose diameter continually increases, end by becoming torn into shreds that dissolve in the moisture of the air. The rings of smoke that are observed in calm weather around guns at the moment of firing have the same origin, although

they are of a very different nature and spread horizontally to a certain distance. With vertical howitzers the rings are horizontal and very beautiful. There is a well known amusement which consists in making small rings issue from a square card-board box by striking

FIG. 13.

one of its surfaces, which is of cloth and opposite the aperture. The rings that make their exit from this spread to a certain distance before breaking. The steam that makes its exit from a vertical eduction pipe often assumes the form of circular or elliptical rings. In short, in this article and that which precedes, I have established the following facts: The similitude of color and form between electro-chemical, thermic, and chemical rings; analogies of form between simple electro-chemical, electro-static, electro-dynamic, and electro-induced rings and hydro-dynamic ones; and analogies of form between multiple electro-chemical, thermic, chemical, and hydro-dynamic rings.

Different experimenters have established analogies of form and color between the optical rings obtained by tempering, by sudden expansion or contraction and compression, and the acoustic ones of vibrating plates. I have shown that these forms are analogous to those of hydro-dynamic rings. Mr. Guebhard has proved theoretically and experimentally that the equipotential figures of the flow of electricity (electro-chemical rings) are identical with the curves of level of the

FIG. 14.

flow of liquids, represented by the general equation of Lame:

$$\frac{d^2\varphi}{dx^2} + \frac{d^2\varphi}{dy^2} = 0.$$

I have demonstrated, on my part, that hydro-dynamic rings (representing lines of the flow of liquids) are analogous to electro-chemical ones; whence results the analogy, if not the similitude, between hydro-dynamic rings and curves of level; analogies of form between simple electro-chemical rings and those caused by a vibrating rod on circular liquid surfaces and upon circular pellicles of glyceric liquid; and analogies between hydro-dynamic rings, and those obtained by shock of liquids or powders upon a glass plate. As for other simple annular forms, they are more or less intimately connected with some of those that precede. In a word, an analogy is established between the following rings: electro-chemical, electro-static, electro-dynamic, thermic, chemical, optical, hydro-dynamic, equipotential flow of electricity, curves of level, rings of liquid surfaces and of circular pellicles, acoustic figures of vibrating plates, and rings through shock and by blowing powder, liquids, air, and smoke.

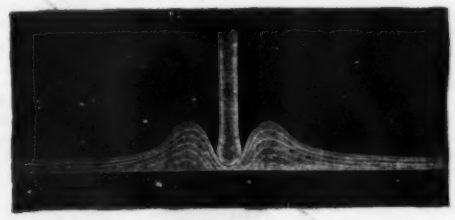


FIG. 15.

From what precedes, we may finally conclude that matter in a solid, liquid, or gaseous state is capable of effecting undulatory or vibratory motions which are shown by annular forms that have the greatest analogy to each other, despite the diversity of causes that produced them; whence we may infer the analogy of the causes from the analogy of the effects that they produce.—*C. Decharme, in La Lumière Electrique.*

ON PAGE'S ELECTRIC LOCOMOTIVE.

VERY soon after Faraday's discovery of magneto-electricity, many devices were invented to utilize a current of electricity to produce mechanical motions, and among the first to do this successfully was Page of Salem, whose ingenious attempts on both small and large scales are no small part of the early history of electro-mechanics. Some of his inventions make a part of every cabinet of apparatus to-day, and in the same

FIG. 16.

shape as they were figured in the first edition of Davis' Manual of Magnetism, issued about forty years ago, and soon found places in the natural philosophies of those days. His "revolving armature," making 6,000 revolutions per minute, was the type of the modern motor. The most ambitious attempt was the electric locomotive, which Page made about 1850, and actually put upon the railroad between Washington City and Bladensburg, Md. It attained a speed of nineteen miles an hour, and altogether weighed 10 tons. It carried its own battery, which Mr. Farmer says consisted of 100 Grove cells. Page expected it would be equal to a ten horse power steam locomotive, but in those days there was no known method of measuring the energy of electricity. Now it is possible to know approximately what he must have had when we know what his source of electricity was. One hundred Grove cells in good working order would have an electromotive force of 180 volts. Suppose that ten horse power had been developed with such an electromotive force; one may compute the current strength and the resistance in the circuit.

$$\frac{EC}{7+6} = 10 \text{ horse power.}$$

$$E = 180.$$

$$180\ C = 7{,}460 \text{ watts; and}$$

$$\frac{7{,}460}{180} = C = 41{\cdot}4 \text{ amperes.}$$

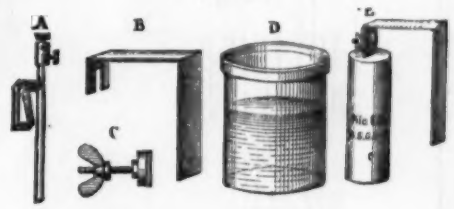
$$\text{As } \frac{180}{R} = 41{\cdot}4,\ R = 4{\cdot}3 \text{ ohms.}$$

That is, his total circuit could have had but 4·3 ohms resistance. That the circuit employed had any such low figure has not the least degree of probability, for, allowing that the resistance of each cell was but one-hundredth of an ohm, which is extremely unlikely, the external energy would be spent in the 3·4 ohms external resistance, and the actual horse power recovered proportionally reduced. It is much more than likely that the internal resistance of the battery itself was as much as four ohms, or would have been that after a very few minutes' use. As for the external resistance or that of the machine itself, I have no data. Assuming that it was 5·7 ohms, and that the total resistance was 10 ohms, then the current was 18 amperes, and the energy $180 \times 18 = 3{,}240$ watts, or 4·3 horse power for the circuit and 2·45 horse power in the machine. Other deductions ought to be made from the above results, for while 100 Grove cells have an electromotive force of 180 volts when freshly set up, there is a very marked falling off in practice, from lack of perfect insulation. Even when the insulation is what is commercially called good, there is an observed loss of as much as ten per cent. for a hundred volts, and it is not likely that in a moving battery of 100 cells there would be an available electromotive force of greater than 150 or 160 volts at the beginning of the experiment. In half an hour of work through such a short circuit as is here supposed, the electromotive force and resistance would have fallen off very materially. The impracticability of galvanic batteries for electro-mechanical work was learned by costly experience, and it does seem strange that the dynamo was not sooner developed, especially as all the novelties in the modern one are only details, and not in fundamental principles; but what to us may seem so obvious that if one had but given proper thought to it it might have been at once seen, was not so obvious until experiments had been made. The incandescent electric lamp is obvious enough now, but the defamers of the attempts to produce them have not all been buried. The modern dynamo is mechanically well nigh a perfect machine, and there is but small margin for its improvement; but that its theory is not completely mastered is obvious to one who listened to the papers at the Philadelphia Conference last fall, and from the statement of one of the eminent electricians there. Speaking of a certain machine, he says that when it is made in accordance with known electrical conditions it would not go at all, and when it is made in defiance of all such principles, it will go.—*A. E. Dolbear.*

O'KEENAN'S NEW ELECTRIC PILE.

THE pile which we figure herewith, and which its inventor, Mr. C. E. O'Keenan, calls a 'Primo-secondary pile," is somewhat different from all apparatus of the

FIG. 1.



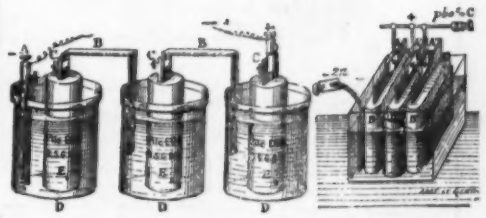
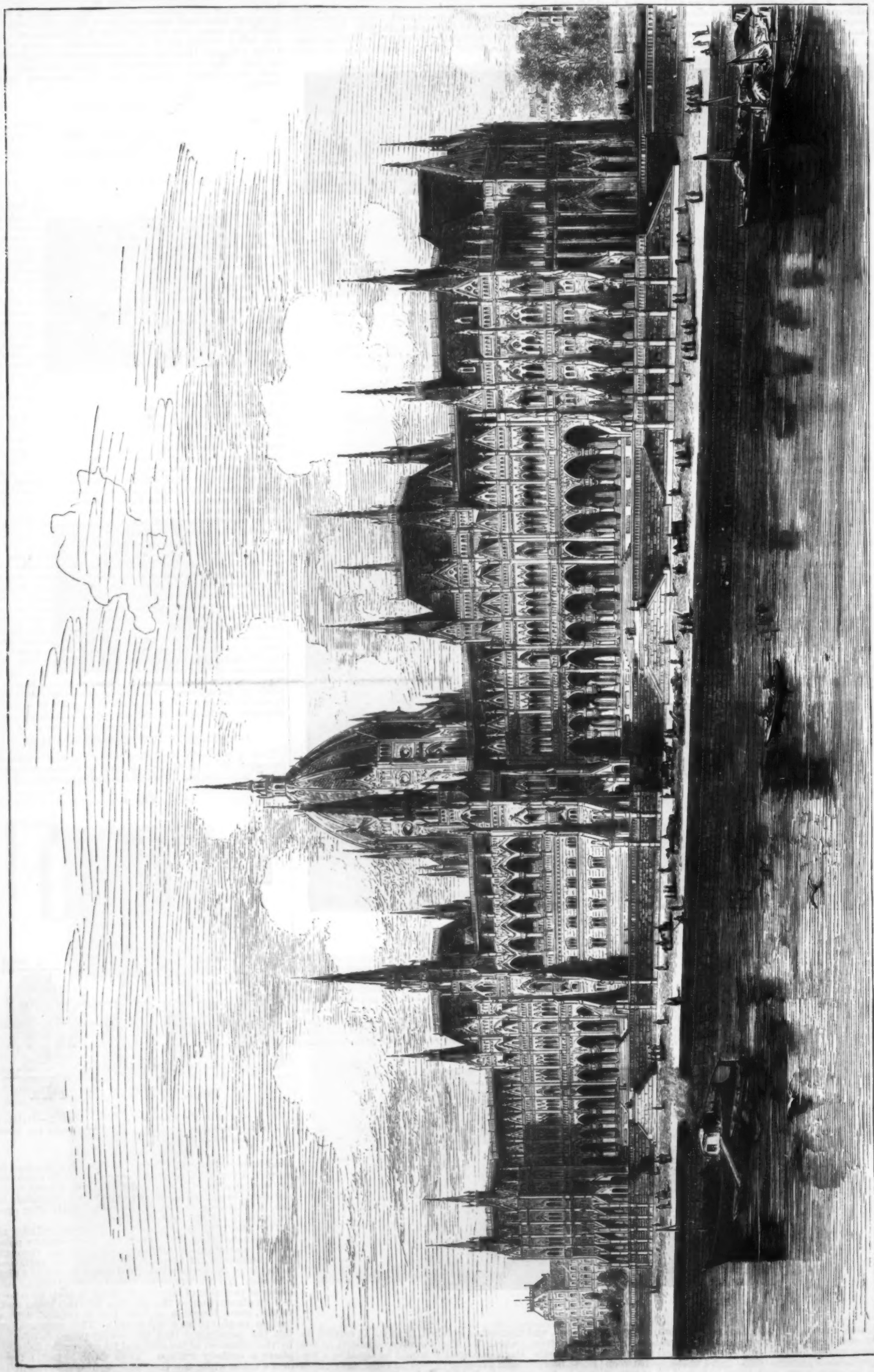


FIG. 2. FIG. 3.

FIG. 1.—Details of O'Keenan's Pile. FIG. 2.—Battery of Elements in Tension. FIG. 3.—Model for Electric Lighting.

kind hitherto known. In fact, its inventor has had in view (1) a very energetic primary pile, and (2) a secondary one capable of lasting indefinitely, as it were, without there being any need, as in all the accumulators in use, of changing the oxidized positive plate after operating for a certain length of time.

The pile (Fig. 1) consists of a plate or cylinder of amalgamated zinc, that constitutes the negative pole, and of a solution of sulphuric acid (obtained through the combustion of sulphur, or purified by agitation with oil) in the proportion of 600 grains of acid to a pint of water. To this liquid are added a few grains of sulphate of peroxide of mercury in order to keep up a perfect amalgamation (as the zinc dips into this bath), and, finally, some binoxide of lead put in contact with a carbon employed as a depolarizer. This arrangement has the peculiarity that the motive power developed by the oxidation of the zinc and its conversion into sulphate is entirely utilized. Tests show, in fact, a force of 2·4 volts, while the theoretic performance ought to be but 2·36; whence it results that the depolarizer it-



THE NEW PARLIAMENT HOUSE, BUDA-PESTH, HUNGARY.—EMMERICH STEINDL, ARCHITECT.

self furnishes a certain quantity of electromotive force.

This pile, although of small dimensions, is capable of giving a large discharge and can be used for the production of light in small Swan lamps. For telegraphy and domestic uses, Mr. O'Keenan is constructing piles of small size (Fig. 2) in which the porous vessel that contains the oxide of lead is but about 1⅛ inches in diameter and 3¾ inches in height. The zinc is in the form of a thin plate. These elements have greater power than the Leclanche pile, and do not polarize so quickly.

For applications to electric lighting, the elements are made with porous flat vessels (Fig. 3), and are connected for quantity. The number of these vessels varies per element according to the discharge to be obtained. The plate of zinc constituting the negative element is bent in a zigzag manner around the porous vessel.

When this pile is exhausted it may be recharged like an accumulator, but the period of *formation* is avoided. The liquid becomes electrolyzed, the zinc deposits electrolytically upon the zinc forming the negative pole, the oxygen reoxidizes the lead that has been reduced during the discharge, and the acid remains free in the liquid.

The retort carbon, placed in the middle of the binoxide of lead, prevents the formation of those local couples that we find in all peroxide of lead accumulators, and that form between the layer of oxide and the subjacent portion of metallic lead. This advantage is due to two causes, viz.: (1) The difference of potentials in a static state appears to be less between the peroxide and the carbon than between the peroxide and the lead. (2) The carbon cannot seize upon the oxygen of the lead oxide, while, under the same conditions, the metallic lead can partially reduce the peroxide and become converted into suboxide.

In short, this pile appears to practically present the following advantages: (1) Great electromotive power—2·4 volts before any polarization, and 1·8 volts after polarization. (2) No wear, except when the circuit is closed. (3) Low price—the materials entering into its composition making it a really cheap pile. (4) No disengagement of gas. (5) Reversibility. The pile constitutes a genuine accumulator having, so to speak, an unlimited duration, a feature that is of great advantage, especially for telegraphs. After a year or two of service, the elements might be recharged *en masse* by a dynamo machine, in order to put them in their primitive state.—*Le Genie Civil.*

THE HUNGARIAN HOUSE OF PARLIAMENT AT BUDA-PESTH.

THE opposite page, taken from the *Illustrirte Zeitung*, shows Prof. E. Steindl's design for the new House of Parliament at Buda-Pesth. The building will probably cost from $7,000,000 to $8,000,000 before it is completed. On the 23d of May last year the requisite bills were passed, and operations were begun shortly after.

The middle portion of the building projecting from the rear facade is the hall for the House of Lords. The cupola is to be erected above a high circular hall or vestibule, 65 feet in diameter, from which corridors lead to the two large halls at the right and left of the same, the said halls being distinguished from the rest of the building by high roofs and their four corner towers. They are 82 feet long and 72 feet wide. All the halls, rooms, corridors, etc., are to be ornamented very richly with marble, wood, and fresco paintings. The exterior walls are all to be erected of sandstone, and the interior or court walls of brick. The building is to be erected on the Danube quay, parts of the buttresses of the central and corner portions resting on the roadway of the quay.

SMILAX ASPERA.

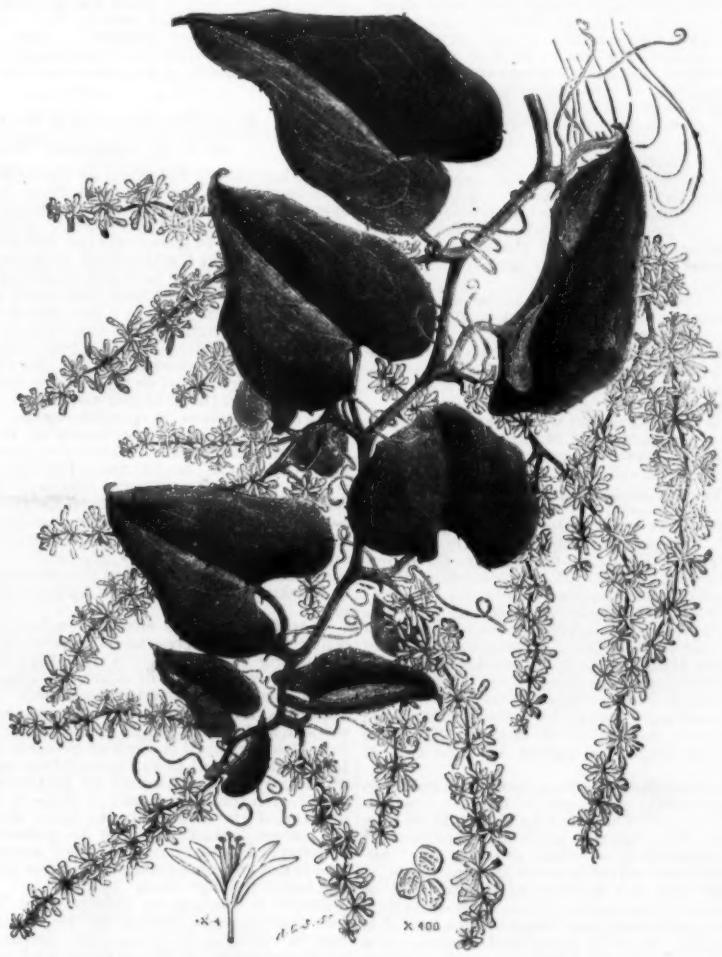
THE smilax of which we publish an illustration is a very beautiful half-hardy evergreen climber well suited for conservatory decoration. It was sent to us by Mr. Burbidge under the name of Smilax tamnoides, but as we were unable to identify it with any species that has received this or a similar appellation, we applied to M. De Candolle, the monographer of the genus in question, who in reply to our inquiry says that it is one of the many forms of Smilax aspera allied to the forms genuina and mauritanica. If the plant is of considerable size (as we believe is the case), it is probably S. aspera var. mauritanica, but the gradations between the two forms are numerous. The group comprising S. aspera and S. pendulina is very distinct in having sessile fascicles of flowers arranged in long spikes. S. aspera is widely diffused in the Mediterranean region, Northern Africa, and India, and presents a well-marked swelling (in the dry state) at the apex of the leaf-stalk, while in S. pendulina, from Madeira, this swelling is not obvious, but the nerves of the leaf pass gradually in the stalk without the intervention of any swelling. The plant from which our figure was taken was grown in a cold greenhouse at Sutton, Co. Dublin, by Mrs. L. Lawrenson. It is, we are informed, planted out in a shady corner of a cool peat bed, and is trained up the side wall and roof. Its leaves are useful in all seasons for cutting, and they endure fresh in water for many weeks. The species of smilax bear their greenish male and female flowers respectively on different plants, the female flowers being succeeded by a roundish purplish berry. —*The Gardeners' Chronicle.*

THE PHYLLOXERA AT THE TURIN EXHIBITION.

By P. LE NEVE FOSTER.

IT was a happy idea on the part of the organizers of the Turin Exhibition, during the International Congress on the Phylloxera, lately held in that city, to gather together in a small building, situated near the marine department, a collection relating not only to the natural history of this insect, which has caused such ruin in the wine-growing districts of France and other countries, but also the various plans that have been adopted for the destruction of this pest.

The *Phylloxera vastatrix* first made its appearance in Europe in 1863, at Pujault, in the department of Gard, and M. Planchon, of Montpellier, appears to have been the first naturalist to study the habits of this parasite. It was not, however, until the 18th August, 1879, that the phylloxera visited Italy, at Valmadrera (province of Como), and in the following March was discovered at Riesi, in Sicily, while in the autumn of the same year it made its appearance at Porto Maurizio and at Messina. Like most insects, the phylloxera undergoes numerous modifications or metamorphoses during its existence, which may be said to be of two distinct characters, viz., that in the air, and that below ground. The principal phases in the life of this insect are, 1st, that of larva; 2d, as an apterous female egg layer; 3d, as a nymph; 4th, as a winged female; 5th, as sexual individual. In the first, it is microscopic, and of a yellow color; in the next, of larger size, and exceedingly prolific, and of a darker color. The female insect, which is larger than the male, during the months of August or September deposits on the leaves two or three eggs, and the little insects, as soon as they are hatched, puncture the leaves, and so cause excrescences or galls to be formed, in which the insects develop, and soon commence laying eggs; these eggs, in due time, give birth to young, which soon become egg-laying mothers, and, like the first, remain wingless; some of these travel down from the branches to the roots, where they obtain their nourishment at the expense of the vine. Five or six generations of these egg-producing mothers follow each other in succession, when some of the individuals begin to acquire wings, and commence to issue from the ground, and rise in the air, until the autumn, and spread to new vineyards, where they lay two or three eggs, and then perish. These eggs, in the course of a fortnight, produce sexual individuals, which appear to exist for no other purpose than that of reproduction; are without means of flight or of taking food. The female lays one egg, called a winter egg, which usually passes the winter unhatched, and is deposited in crevices, or under the loose bark of the old wood,



SMILAX ASPERA, VAR.—FLOWERS GREENISH-YELLOW, FRAGRANT.

the young of which either go directly to the roots and form root-feeding colonies, or gall-inhabiting colonies on the leaves. The last occur only in the form of apterous females, and are not essential to the propagation of species, and do, as compared with the root-inhabiting type, but little damage.

When first attacked, the vine shows no signs of infection, as the insect is only visible by aid of a lens, and the vegetation does not suffer for the first year. If, however, the roots are carefully examined, small excrescences of a whitish color will be observed, and these are caused by the puncture of the insect, and it is in these that the root-dwelling type lives, multiplies, and hibernates, and it is in consequence of these wounds that the roots become no longer capable of furnishing nourishment to the vine. During the second year, the plant begins to shows signs of decline, the vegetation languishes, the shoots cease to grow, the leaves become pale in color, and the scanty bunches of grapes rarely come to maturity; and, finally, the insect having exhausted the plant, abandons its lodgings for a more suitable one among the neighboring healthy vines, and the injured plant, the roots of which are no longer capable of performing their natural functions, usually dies during the third year.

Among the many plans which have been suggested and tried, in order to get rid of this pest, but none have as yet really given satisfactory results, and this is easily explained from the fact that any agent employed for the destruction of the phylloxera must penetrate at least one meter deep into the ground in order to reach it, and while capable of killing the insect must, at the same time, do no injury to the vine. Carbolic acid, petroleum, sulphide of lime, flowers of sulphur, subacetate of copper, tobacco juice, carbonic acid, chloride of lime, and a variety of other insect destroyers have been tried in due turn. Some viticulturists recommend the planting of garlic or hemp between the rows of vines, while the Academy of Sciences of Paris, in 1874, advised the spreading of sulphide of ammonia over the infected vineyards. The flooding of the vineyards, in order to drown out the insect, has also been recommended, and where it has been possible to apply such a remedy it has been entirely successful; but as vineyards are usually situated on hilly ground, it will be readily understood that this remedy is inapplicable in the majority of cases.

Another remedy that has been adopted, and which on account of the cost is clearly impracticable, is the substitution of sand for the earth in which the vines are grown, it having been found that the plants growing in a sandy soil are, to a certain extent, not attacked by the phylloxera.

The principal remedy, however, is the application of bisulphide of carbon, by injecting it into the ground, usually in a liquid state, by means of special implements that have been devised for the purpose, but great care must be taken to regulate the quantity in order to effect the object, and without injuring the vines. In any case this method is very costly, besides it being necessary afterward to manure the plants before they completely recover from the effects of the attack.

In many cases the wisest course to pursue is to destroy the vineyard entirely, to cultivate the land with care, and then to replant it with vines capable of resisting the attack of the phylloxera.

The cultivation of the American vine, many varieties of which are proof against the assaults of this pest, has found a large number of partisans, it having in many cases given highly satisfactory results, some varieties, such as the Jacquez, Herbemont, Cornucopia, Othello, and Canada, being grown for the direct production of grapes, while others, comprising the different varieties of the Vitis Riparia and Vitis Rupestris, viz., York's Madeira, Solonis, Vialla, Jacquez, Oporto, and Taylor, are planted, and serve as stocks to be afterward grafted with the different kind of grapes suitable for the particular district and for the special description of wine it is desired to produce.

The Italian Government have done all in their power to encourage the cultivation of the American vine, and for this purpose obtained from America a quantity of seed, of which 6,760 lb. was distributed, since 1879, among the various local agricultural societies and private vine growers.

The Minister of Agriculture has assigned five gold medals, ten silver, and twenty bronze to exhibitors in this section, and the Direction of Agriculture exhibits an important collection of maps, showing the districts invested with the phylloxera, drawings, photographs, and a quantity of reports and other pamphlets relating to this insect, and besides this, samples of the various tools and implements used for destroying the infected vineyards, as well as those employed for the injection of the bisulphide of carbon.

The Minister of Agriculture also shows an important monograph with diagrams illustrating the various processes adapted to the manufacture of the bisulphide of carbon by the methods of Peroncelli, Giraud and Aubert, Gally, Cazalet, and Deiss. The first manufactory of this substance in Italy was at Oneglia and Pisa, and at the beginning of the present year there were four factories in Tuscany, six in the southern provinces, three in Sicily, and one at Milan, making in all fourteen establishments, containing seventy retorts, of which sixty are in use for about eight months during the year. The process principally adopted is that of Deiss; the

quantity of sulphur required for each furnace of four retorts is from six to eight quintals (12 cwt. to 16 cwt.) per day, and which in 240 working days produce from 1,800 tons to 2,000 tons of bisulphide of carbon, a large quantity of which is being used in other industries, and some is exported to Tunis.

The Italian Government have purchased, since 1880, all the bisulphide of carbon required for the treatment of the vineyards in the localities ravaged by the phylloxera, from Italian manufacturers, the quantities and value being as follows:

	Quintals.	Lire.
1879	26·78	1,279·00
1880	1,314·24	58,878·05
1881	1,461·75	56,205·87
1882	1,986·48	72,996·26
1883	5,886·35	200,818·05
1884	1,085·20	37,528·20
Total	11,760·80	427,701·43

The Minister of Agriculture of France (Ecole Nationale d'Agriculture of Montpellier) has sent a quantity of photographs, maps, reports, books, etc., respecting the phylloxera, besides models, diagrams, preparations, roots, and dried specimens of vines illustrative of the damage done by this insect; a variety of drawings, photographs, and examples of grafting in various stages; a large quantity of tools and implements used for grafting, among the best of which may be mentioned those of Trabua, Petit, Saint-Cristole, and Guisquet; a collection illustrating the resisting qualities of the American vine, commencing with the seed, microscopic and other preparations of the roots; samples of wine produced from American grapes; drawings, photographs, and implements illustrating the various systems adopted for the destruction of the phylloxera, viz., by the bisulphide of carbon method, the sulpho-carbonate of potassa method, sulpho-carbonate of lime method, as well as those of other insect-destroying substances; the treatment of vineyards by flooding, and that by the use of sand, with specimens and analysis of sands in which the vines resist the attack of the insect, and specimens, with analysis, of those in which it does not.

The Minister of Public Works, Portugal, contributes a collection of reports and regulations respecting the spread of this pest in that country.

The Swiss Government also send a collection of reports, regulations, and other books relating to the phylloxera, together with maps of the infested localities, instruments of and tools used for the inspection of vineyards, etc.

The School of Viticulture, of Alba, shows a variety of tools and implements for grafting and pruning vines, as well as those used for the application of sulphur, a variety of maps, pamphlets, herbariums, diagrams illustrating the various diseases to which the vine is subject, herbariums of American vines, models and microscopic preparations for the study of the phylloxera.

The schools of viticulture and winemaking of Avellano, Cornegliano, Grumello del Monte, and numerous other institutions, exhibit important collections, etc., illustrative of the various diseases which affect the vine, and the numerous parasites which infest it, as well as tools, implements, etc., of every description.

One of the most interesting entomological collections is that of M. F. Richter, of Montpellier, who exhibits twelve slides for the microscope to illustrate the different metamorphoses of the *Phylloxera vastatrix* (Planchon); six slides of the *Phylloxera quercus* (Boyer); *Phylloxera œcinea* (Heyden); *Phylloxera corticalis* (Kaltenbach); *Phylloxera punctata* (Lichtenstein); *Phylloxera acanthochermes* (Kollar); *Aploneura Lentisci* (Passerini); and of the *Phylloxera salicis* (Lichtenstein). Besides various preparations in spirits of wine of the galls on the leaves and excrescences in the roots.

Samples of grafting shown by other exhibitors; among them may be mentioned M. Blanc, of St. Gilles (Gard), who shows samples of fifteen different ways of grafting.

Most numerous are the systems proposed for grafting, among which the whip graft (*griffe anglaise*), which is recommended as one of the best by the congress lately held in Turin; the Champin graft also is advocated by numerous viticulturists; while grafting by "approach" may be found advantageous in many cases.

The American vine has become of greater and of more comprehensive importance, on account of its now well established phylloxera-resisting qualities, and it is now grown largely, both in Italy and France, as a grafting stock for European kinds, as well as being largely planted for direct production. The Count di Rosenda exhibits wine made in 1883, from the Solonis, Concordia, York's Madeira, and Elsimburg varieties of the American grape. Dr. Garroni, of Varese, wine made in 1882 and 1883, from the York's Madeira grapes. Signor Borghi, of Varese, also sends samples of wine made from York's Madeira, Clinton, and Vialla.

An important exhibit is that of Dr. Rizzetti, who, besides a collection of 75 varieties of the American vine cultivated in the grounds, shows a collection in pots of 50 seedlings of the *vitis rubris*, and 50 seedlings of the *vitis riparia silvestris*, sown last May; also 27 plants of Italian varieties grafted on American stocks. A herbarium containing 80 specimens of American vines, with a descriptive catalogue which cannot fail to be of great interest to the viticulturist. In addition to these are exhibited 80 different varieties of seed of American grapes, and a number of slides prepared for the microscope, illustrating the power of resistance of the American against the attack of the phylloxera, as compared with that of the European sorts.

Dr. Rizzetti has established on the hills at Mongreno, a few miles distant from Turin, a nursery for raising this quality of vine, and has at the present time upward of 100,000 seedlings belonging to thirteen different species, viz., the Riparia, Æstivalis, Labrusca, California, Candicans, Rotundifolia, Cinerea, Cordifolia, Rupestris, Arizonica, Lincocumini, Monticola, and Rubia, which last has only recently been introduced into Europe, and is highly esteemed on account of its resisting qualities. These thirteen species are subdivided into seventy-eight varieties, of which twenty-five varieties belong to the Æstivalis species, among which may be mentioned the Jacques, Herbemont, Norton's Virginia, and York's Madeira, which last are specially adapted for the direct production of grapes, while the twenty-two varieties of the Riparia are suitable as grafting stocks for European kinds, and the other thirty-one varieties belong to the remaining eleven species, which are all more or less suitable for planting in different localities.

Notwithstanding the advantages offered by this description of vine, on account of its phylloxera-resisting qualities, it will be readily understood that viticulturists in general will be loth to replace the vines in full produce in their vineyards with young plants, the yield from which, for many years to come, must be insignificant.

Mr. F. Cassetta, of Alba, meets this difficulty in the following way: By grafting on to existing Italian vines new roots of the American sorts, and that without disturbing in any way the economic conditions of the vineyard. To an existing vine he grafts on, as near the ground as it is possible, a scion of some American variety, which pushes rapidly with great vigor, and by the following spring this new shoot is sufficiently long to be bent down into the ground as a layer, leaving the extremity above the surface; this layer naturally soon takes root, and should the dreaded phylloxera make its appearance, it is only necessary to sever the vine from its old roots, and in this manner it continues to grow with great vigor on the young and healthy ones that have been prepared for it. The advantages offered by this system over that of the replanting of the vineyards with young American plants, to be afterward grafted with European sorts, cannot fail to be obvious to all viticulturists, for in the latter case many years must elapse before the new vines can be in full bearing, while in the former the wine harvest is not lost for a single year.

Signor Cassetta shows an Italian vine of the variety known as *Barbera*, with a graft of York's Madeira, made last May, to be layered next spring. Also a vine of the same quality grafted with York's Madeira in the spring of 1882, which graft was propagated as a layer in the spring of 1883, and in the month of May of the past year was separated from its old roots. During all this period the vine did not cease to produce the usual quantity of grapes.—*Jour. Soc. of Arts.*

ZINC IN DRINKING WATER.

By F. P. VENABLE, Ph.D.

THE increase in the use of galvanized iron, especially in the form of water tanks and pipes, has led to a reopening of the question as to the possible injurious effects from the use of such water. It is a matter of importance, then, to us how far our knowledge extends on this subject, and I will collect here all of the known facts so far as I have been able to get at them.

The so-called galvanized iron is of course nothing more than iron dipped in a bath of zinc, and so superficially coated with it and to a certain extent alloyed with it. The character of the protection afforded the iron is galvanic (hence the name), the two metals forming a galvanic couple, so that under the action of any exciting liquid the zinc and not the iron is attacked. That zinc dissolves in potable waters has long since been shown by the experiments of Boutigny, Schaueffele, and Langonne. Distilled water and rain water dissolve it more readily than hard water. Especially is water containing carbonic acid capable of this solvent action. So much may be taken up that the water becomes opalescent and acquires a distinctly metallic taste. It seems that by the action of water, hydrate and carbonate of zinc are gradually formed, and that this action is more rapid in the presence of certain saline matters, but is weakened by the presence of calcium salts.

As to the injurious effect of such waters, authorities differ. Fonssagrives has investigated the question, consulting the statistics of the French navy and the recorded experiments of others, adding, however, none of his own. The French government had, before this, appointed a committee to make special report on the subject, and the investigations of Roux, in 1865 and 1866, furnished evidence enough of possible injury to health from water stored in galvanized iron tanks to lead to an order from the Minister of Marine prohibiting the use of such tanks on board of ships of war. Boutigny attributed grave effects to the use of these zinc-containing waters, looking upon it as probably resulting in epilepsy. Fonssagrives, however, maintains that the zinc is not cumulative, and produces no bad effects unless taken in large doses.

Doubt is thrown on this position, however, by the fact that his assertions as to the limited solubility of zinc in ordinary drinking-water are not sustained by by experiments. Without doubt such waters have been used for considerable lengths of time, and no injurious effects have been noticed. This may have been due, however, to the hardness of the water, and hence the small amount of zinc dissolved. Pappenhein states in contradiction to the assertion of Fonssagrives that zinc vessels are dangerous, and must be carefully avoided. Dr. Osborne, of Bitterne, has frequently observed injurious effects from the use of waters impregnated with zinc. Dr. Stevenson* has noticed the solvent action of rain-water on galvanized iron, and states that probably its continued use would cause injury to health. He recommends as a convenient test for the presence of zinc in potable waters the addition of potassium ferrocyanide to the filtered and acidulated water. Zinc gives a faint white cloud or a heavier precipitate when more is present. Dr. Frankland† mentions a case of zinc poisoning where well-water, containing much dissolved oxygen and but little carbonic acid, was used after passing through galvanized iron pipes. Professor Heaton‡ has recorded the analysis of a spring water in Wales, and a second analysis of the same water after passing through half a mile of galvanized iron pipe, showing that the water had taken up 6·41 grains of zinc carbonate per gallon.

A similar instance of zinc-impregnated water has come under my own observation, and I append the analytical results. The water from a spring 200 yards distant was brought by galvanized iron pipes to a dwelling-house, and there stored in a zinc-lined tank which was painted with white lead. The water became somewhat turbid and metallic-tasting, and its use for drinking purposes was discontinued. Analyses were made after the pipes had been in use about one year. A somewhat full analysis of the spring water was made, under my direction, by Mr. J. C. Roberts. The analyses of water from the tank and directly from the pipe I carried out only so far as zinc, iron, and tests for lead were concerned. The results are calculated in grains per gallon of 231 cubic inches:

Analysis of Spring.

Silica	2·45 grains.
Lime	0·23 "
Magnesia	0·17 "
Alkalies	0·43 "
Chlorine	0·35 "
Sulphuric acid	0·19 "
Carbon dioxide (calculated)	0·45 "
Total residue on evaporation	4·34 "

The tank contained 4·48 grains of zinc carbonate per gallon, with a trace of iron and no lead. Water from the pipe gave 4·29 grains of zinc carbonate per gallon and a trace of iron.

It is evident, then, when the dangerous nature of zinc as a poison is taken into consideration, that the use of zinc-coated vessels in connection with water or any food-liquid should be avoided.—*Journal of the American Chemical Society.*

* *Chemical News*, xlix., 107.
† *Ibid.*, xlix., 115.
‡ *Ibid.*, xlix., 85.

BOTTLE EXPLOSIONS.

A WELL known method of loosening refractory glass stoppers is to heat the neck of the bottle to which they adhere, a plan which often results in liberating the stopper when all other means have failed. A warning against the method comes from Japan. Dr. Driver, the principal of the Imperial College of Engineering at Tokio, was attempting to open a bottle of trichloride of phosphorus in this manner, when, through some decomposition having taken place, the contents exploded, broke the bottle to fragments, and seriously injured one of the Professor's eyes. Should any photographer attempt such a plan with an ammonia bottle, for instance, results equally deplorable might readily ensue, unless great care were exercised in the manner of applying the heat and *protecting the bottle.—Brit. Jour. of Photo.*

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